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14. ABSTRACT <p>The overall objective of this project was to field, demonstrate and evaluate the effectiveness of two technologies for characterizing coastal contaminant migration. The specific objectives of this demonstration were to demonstrate (1) that the Trident probe can be used to help delineate areas where groundwater seepage is occurring and Contaminant of Concern concentrations in those areas, (2) that the UltraSeep system can be used to quantify the flow of groundwater and concentration of contaminants that may be impinging on the surface water system, (3) the technology to end-users to determine the utility of these tools for making decisions at DoD coastal landfills and hazardous waste sites, and (4) the quantification of the costs associated with the operation of each technology. The first demonstration was at Naval Support Activity Panama City. The Trident probe was used successfully to identify areas of groundwater discharge from the site to the surface waters of St. Andrews Bay, and the UltraSeep was used successfully to quantify groundwater discharge rates and volatile organic compound (VOC) discharge concentrations in two discharge zones identified with the Trident probe. The second demonstration was performed at the former Naval Training Center Orlando. The Trident probe successfully identified areas of groundwater discharge from the site to the surface waters of Druid Lake and the UltraSeep successfully quantified groundwater discharge rates and VOC discharge concentrations in two discharge zones identified with the Trident probe. The cost analysis indicated that the cost of an integrated Trident probe/UltraSeep survey is expected to be on the order of \$120K, which represents a cost savings of about 42% relative to the estimated cost for the baseline technology of about \$210K. In addition, the demonstration at the NSA Panama City site documented an additional cost avoidance of about \$1.25M based on support for selection of Monitored Natural Attenuation as the corrective action at the site. The Trident probe and UltraSeep have generally found strong acceptance by stakeholders and end-users. The direct nature of the measurement technology helps to reduce uncertainties that have plagued these sites in the past.</p>					
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EXECUTIVE SUMMARY

Increasingly, groundwater is being recognized as a potentially significant, although poorly quantified, source of nutrients and contaminant materials to coastal ecosystems. The Department of Defense (DoD) and other government and private entities are in the process of identifying, assessing, and remediating a large number of terrestrial hazardous waste sites. Many of these sites are located adjacent to harbors, bays, estuaries, wetlands, and other coastal environments. It is estimated that approximately one-third of all Navy landfills have groundwater infiltrating the waste. A general requirement exists to determine if contaminants from these sites are migrating into marine and surface water systems at levels that could pose a threat to the environment.

Currently, these problems are evaluated by the use of hydraulic head measurement in shore-side wells and/or numerical models that provide theoretical predictions of flow and contaminant migration. However, these measurements and models are of limited utility in areas adjacent to marine systems where tides, waves, and strong density gradients make it difficult to establish boundary conditions. In addition, current techniques for verifying the model predictions are inadequate.

Historically, two major obstacles in studying groundwater exchange have been (1) identifying the spatial location where exchange is likely to take place, and (2) accurately measuring the groundwater seepage across the sediment-water interface. Following a review of existing technologies, the Navy's Pollution Abatement Ashore (0817) program sponsored the development of new monitoring methodologies to augment and validate models for groundwater fate and transport at these sites, and to determine the extent of the waste site's contribution to a particular waterway, bay, or estuary.

A series of technologies were investigated for their applicability toward direct quantification of coastal contaminant migration via groundwater, and two prototypes were developed. The technologies include a screening probe for determining where groundwater may be discharging (the Trident probe), and an integrated seepage meter and water sampling system (the UltraSeep) for quantifying discharge rates and chemical loading.

The Trident probe is a combined conductivity sensor, porewater sampler, and temperature sensor probe that utilizes salinity, temperature, and chemical contrasts between groundwater and surface water to map areas of potential groundwater discharge. The UltraSeep system is an integrated ultrasonic seepage meter and water sampling system for quantifying discharge rates and chemical loading from groundwater flow to coastal waters. The goal of this demonstration was to provide full-scale evaluation of the commercialized versions of these technologies at relevant DoD sites.

Site selection criteria were developed for the demonstration, providing the basis for selection of two sites. The Naval Support Activity (NSA) Panama City site was an ideal candidate for the demonstration of these technologies. The demonstration focused on evaluation of a VOC plume associated with AOC 1 at NSA Panama City.

The site was adjacent to St. Andrews Bay, and the plume appeared to be migrating toward the bay. Although groundwater discharge rates were unknown, there was a clearly defined hydraulic gradient toward St. Andrews Bay from AOC 1. There was also a strong salinity gradient, with most of the monitoring wells indicating fresh water, and high-salinity water in St. Andrews Bay. The 1,1-DCE was distinctive from any background contamination in the bay, thus reducing potential confounding influences of natural/background sources.

The site selected for the second demonstration was Naval Training Center (NTC) Orlando, Operable Unit 4 (OU 4). The site was selected based on its compliance with the selection criteria, and its contrast to the NSA Panama City site used for the first demonstration. There was little or no salinity or conductivity gradient between groundwater wells adjacent to Lake Druid and surface waters in the lake, but temperatures appeared to contrast enough to detect possible groundwater seepages using the Trident probe. The NTC Orlando site was significantly different from the Panama City site in that it was a freshwater lake environment with no tidal influence, and had significantly higher CoC levels. The primary target CoC (tetrachloroethene [PCE]) was also different than the primary target for NSA Panama City (1,1-DCE). Thus, the NTC Orlando site helped to test the range of applicability of the technologies.

At the NSA Panama City site, the Trident probe was used successfully to identify areas of groundwater discharge from the site to the surface waters of St. Andrews Bay. Thirty offshore stations were sampled with the probe sensors and water sampler. The zone of discharge appeared to limited to a band extending parallel to shore between about 100 to 300 ft offshore. All VOC analytes, including DCE at all Trident probe stations, were below the PQL. No detectable DCE or other VOCs were measured in the sub-surface or surface water in the groundwater discharge areas identified with the Trident probe sensors. The results from shallow (2 ft) piezometers installed on Transect T3 validated the results from the Trident probe.

The UltraSeep was used successfully at the NSA Panama City site to quantify groundwater discharge rates and VOC discharge concentrations in two discharge zones identified with the Trident probe. At station T4-4, groundwater discharge was always positive, with rates ranging from about 2 to 8 cm/d, and a 24-hour mean discharge rate of 5.1 cm/d. At station T3-3, groundwater discharge was always positive, with rates ranging from about 1 to 5 cm/d and a 24-hour mean discharge rate of 2.7 cm/d. The positive discharge at these locations was consistent with the results from the Trident probe survey.

Although groundwater discharge was detected at both stations, all target VOC analytes, including DCE in all UltraSeep samples, were below the PQL. Results from three shallow piezometers installed adjacent to each UltraSeep station validated the UltraSeep results. Overall, the NSA Panama City demonstration was successful in demonstrating the utility of the Trident probe and UltraSeep in assessing coastal contaminant migration. No DCE discharge into St. Andrews Bay at levels above the SWCTL of 3.2 µg/L was detected. Thus, study results support the selection of monitored natural attenuation as a corrective action alternative for the site.

The second demonstration was performed at the former NTC Orlando, Orlando, Florida. The primary contaminant of concern at OU 4 NTC Orlando was PCE and its degradation products, which have been detected at concentrations exceeding the surface water cleanup target level along the shoreline of Druid Lake. An extraction and treatment system had been installed; however, it was unclear whether VOCs were continuing to enter the lake and at what rate.

The Trident probe was used successfully to identify areas of groundwater discharge from the site to the surface waters of Lake Druid. Thirty-one offshore stations were sampled with the probe sensors and water sampler. Two zones of potential groundwater discharge were successfully identified. One near-shore band appeared to be extending parallel to the shoreline about 50 to 100 ft offshore. Another zone that was previously unknown extends 200 to 300 ft offshore. Detectable levels of PCE, TCE, DCE, vinyl chloride (VC), and/or other

VOCs were measured in either the sub-surface or surface water in the areas of groundwater discharge identified with the Trident probe sensors. The results from shallow (2 ft) piezometers validated the Trident probe results.

The UltraSeep successfully quantified groundwater discharge rates and VOC discharge concentrations in two discharge zones identified with the Trident probe screening. The strongest discharge was in the near-shore discharge zone at station T3-7. The groundwater discharge was always positive, with rates ranging from about 12 to 16 cm/day, and a 24-hour mean discharge rate of 12.7 cm/day. At station T2-5, groundwater discharge was always positive, with rates ranging from about 2 to 4 cm/day and a 24-hour mean discharge rate of 2.4 cm/day. The weakest discharge was measured offshore at station T2-3. The groundwater discharge at this site was always positive, with rates ranging from about 0 to 3 cm/day and a 24-hour mean discharge of 1.1 cm/day. The positive discharge at these locations was consistent with the results from the Trident survey.

Discharge concentrations were calculated for the primary VOCs of interest, including PCE, TCE, cis-DCE, and VC, subject to detection. PCE was not detected in the discharge water at any of the three target UltraSeep stations. Station T3-7 had the highest discharge concentrations for TCE, cis-DCE, and VC. TCE was not detected in the discharge waters at stations T2-5 and T2-3, while these stations had comparable discharge concentrations for cis-DCE, and station T2-3 had a slightly higher VC concentration. Variability among replicate calculated discharge concentrations from the last three UltraSeep samples at each site was relatively low, with RSDs ranging from <1% to about 25%.

UltraSeep discharge concentrations were used in conjunction with UltraSeep measured discharge rates to quantify the mass flux of VOCs from groundwater to surface water at the three target stations. The combination of strong discharge rate and high discharge concentrations at station T3-7 lead to a dominant mass flux for VOCs at that station. VOC mass flux at stations T2-5 and T2-3 were comparable for cis-DCE and VC, and non-detect (ND) for TCE.

The UltraSeep sampling validation was based on piezometers installed to a depth of 1 ft at three replicate locations in a triangular pattern around each UltraSeep station. The results indicate general agreement between these shallow piezometer samples and the discharge concentrations determined with the UltraSeep.

At station T2-3, PCE and TCE were both ND, while the mean cis-DCE and VC concentrations were somewhat lower in the UltraSeep discharge, but fell within the range of variability of the triplicate piezometers. PCE and TCE were ND in the UltraSeep discharge, with an estimated upper bound of <1.6 µg/L. This upper bound is consistent with the 0.7 µg/L concentration of PCE detected in the shallow piezometers, but is lower than the TCE concentration detected in the piezometers. Concentrations of cis-DCE and VC were comparable at this station.

At station T3-7, PCE was ND in the UltraSeep discharge and the piezometers. TCE and cis-DCE had comparable concentrations (within the range of variability). For VC, the discharge concentration was higher than for the piezometer, which was ND, with an upper bound of <10 µg/L. Given that this bias was not observed at other stations, this finding suggests that VC may be forming as a degradation product from DCE very near the interface or even in the surface water at this station.

Overall results for the demonstration show how discharge of VOCs to the lake are regulated by the physical pathway and the chemical attenuation that occurs along these pathways,

along with the effects of localized mixing in the lake itself. From the demonstration, it is clear that areas close to shore have the strongest discharge, and the least attenuation of VOCs, whereas the areas further from shore tend to have lower discharge rates and higher attenuation. Near the shore, the shallow water and low mixing, coupled with the higher discharge rates, leads to higher concentrations in the surface water of the lake, whereas further offshore the lower discharge and better mixing generally lead to undetectable VOC concentrations in the surface water. Overall, the project successfully demonstrated the utility of the Trident probe and UltraSeep in assessing coastal contaminant migration.

A cost analysis for the Trident probe and UltraSeep technologies relative to the baseline technologies was developed on the basis of the demonstration, input from the commercial partners and typical site parameters. The cost analysis assumed a coastal area of interrogation measuring 200 ft by 500 ft with 60 Trident probe sensors, 15 Trident porewater, and 5 UltraSeep sampling points. The cost analysis indicated that the cost of an integrated Trident probe/UltraSeep survey is expected to be on the order of \$120K, which represents a cost savings of about 42% relative to the estimated cost for the baseline technology of about \$210K.

Much of the cost difference stems from the higher labor load associated with installing enough micro-wells to provide comparable spatial resolution to the Trident probe system. Additional labor load is also associated with the labor-intensive nature of the Lee meters when trying to provide time-resolved seepage measurements and discharge samples, which are critical in tidally influenced coastal environments. In addition, the demonstration at the NSA Panama City site documented an additional cost avoidance of about \$1.25M based on support for selection of Monitored Natural Attenuation as the corrective action at the site.

ACRONYMS

AC	Alternating Current
AGIS	Advanced Ground Information Systems
AOC 1	Area of Concern 1
ARARs	Applicable or Relevant and Appropriate Requirements
AWTA	Anacostia Watershed Toxics Alliance
BCD	Buoyancy Compensation Device
BRAC	Base Realignment and Closure
Cal/EPA	California Environmental Protection Agency
CAO	Corrective Action Objective
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMS	Corrective Measures Study
CoC	Contaminant of Concern
CoC/SAR	Claim of Custody/Sample Analysis Request
COTS	Commercial Off-the-Shelf
CPR	Cardiopulmonary Resuscitation
CSMs	Conceptual Site Models
CSS	Coastal Systems Station
CY	Calendar Year
DAN	Diver Alert Network
DCE	Dichloroethylene
DI	Deionized
DL	Detection Limit
DLC	Data Logger/Controller Unit
DoD	Department of Defense
DoD	Department of Defense
DPT	Direct-Push Technology
DQOs	Data Quality Objectives
EBS	Environmental Baseline Survey
ESTCP	Environmental Security Technology Certification Program
FDEP	Florida Department of Environmental Protection
FFI	Focused Field Investigation
FRTTR	Federal Remediation Technologies Roundtable
FY	Fiscal Year
GC/MS	GAS Chromatography/Mass Spectrometry
GPS	Global Positioning System

HASP	Health and Safety Plan
HASP	Health and Safety Plan
HMW	High Molecular Weight
HSWA	Hazardous and Solid Waste Amendments
IRA	Interim Remedial Action (IRA)
ISCO	In Situ Chemical Oxidation
ITRC	Interstate Technology Regulatory Cooperation
LCS	Laboratory Control Samples
LMW	Low Molecular Weight
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MNA	Monitored Natural Attenuation
MPS	Media Protection Standard
MQOs	Measurement Quality Objectives
MS/MSD	Matrix Spike Matrix Spike Duplicate
NA	Natural Attenuation
NAVFAC	Naval Facilities Engineering Command
NCBC	Naval Construction Battalion Center
ND	Non-Detect
NFESC	Naval Facilities Engineering Service Center
NIST	National Institute of Standards and Technology
NSA	Naval Support Activity
NTC	Naval Training Center
OPT	Orlando Partnering Team
ORP	Oxidation Reduction Potential
PAHs	Polycyclic Aromatic Hydrocarbons
PAHs	Polynuclear Aromatic Hydrocarbons
PARCC	Precision, Accuracy, Representativeness, Completeness, and/or Comparability
PCE	Tetrachloroethene
PI	Principal Investigator
PQL	Practical Quantitation Limit
PTFE	Polytetrafluoroethylene
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act

RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RI	Remedial Investigation
ROD	Record of Decision
RPD	Relative Percent Difference
RPMs	Remedial Project Managers
RSD	Relative Standard Deviation
SAs	Study Areas
SDG	Submarine Ground Discharge
SERDP	Strategic Environmental Research and Development Program
SOPs	Standard Operating Procedures
SPAWAR	Space and Naval Warfare Command
SSC San Diego	SPAWAR Systems Center San Diego
SWCTL	Surface Water Cleanup Target Level
SWDIV	Southwest Division
SWMUs	Solid Waste Management Units
T3s	Transect Stations
TCE	Trichloroethene
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TtNU.s	Tetra Tech NU.S.
U.S. EPA	United States Environmental Protection Office
VC	Vinyl Chloride
VOC	Volatile Organic Compound
WAAS	Wide-Area Augmentation System

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1. INTRODUCTION

1.1 BACKGROUND

Increasingly, groundwater is being recognized as a potentially significant, although poorly quantified, source of nutrients and contaminant materials to coastal ecosystems. Groundwater discharge (seepage) into coastal and surface water environments has been studied previously using a variety of methods (Lee, 1977; Bokuniewicz, 1992; Taniguchi and Fukuo, 1993; Cable, Burnett, Chanton, and Weatherly, 1996; Moore, 1999; Li, Bary, Stagnitti, and J-Y Parlange, 1999; Chadwick et al., 1999; Paulsen, Smith, O'Rourke, and Wong, 2001). The primary driver for seepage in near-shore environments is generally the discharge from land to surface water induced by the hydraulic gradient in the terrestrial aquifer.

However, significant contribution to seepage may also derive from groundwater circulation and oscillating flow induced by tidal stage (Simmons, 1992; Li et al., 1999). In coastal areas with strong tides, tidal mixing zones may form from the movement of seawater into the aquifer (Figure 1-1). This tidally mixed zone can be important in controlling the exchange of groundwater due to a process referred to as tidal pumping (Moore, 1996). Tidal pumping occurs when seawater mixes with groundwater at high tide, and then as the tide recedes, the mixture of seawater and groundwater is drawn out into the coastal waters. Because this process repeats every tidal cycle, appreciable volumes of groundwater can be extracted over time (Moore, 1996; Valiela and D'Elia, 1990). Tidal pumping can also lead to significant attenuation of contaminant concentrations prior to discharge.

Interest in quantifying the exchange between seepage and overlying surface water has increased due to potential impacts resulting from anthropogenic land uses. Groundwater discharge originates inland and carries with it contaminants or nutrients, dissolved or colloidal, that can impact the chemical budget of surface water ecosystems. For example, previous investigators concluded that groundwater discharge into Flanders Bay on Long Island, New York, accounts for up to 37% of the copper distribution in the bay (Montlucon and Sanudo-Wilhelmy, 2000), and Moore (1996) estimated that seepage accounts for approximately 40% of the total river inputs in a study area in the South Atlantic Bight.

These studies clearly show that groundwater discharge into surface water environments can significantly contribute to the water budget. This impact, both chemical and physical, may be heightened in smaller bodies of water such as embayments or lagoons, due to their limited volume and restricted fluid exchange with the open ocean.

The Department of Defense (DoD) and other government and private entities are in the process of identifying, assessing, and remediating a large number of terrestrial hazardous waste sites. Many of these sites are located adjacent to harbors, bays, estuaries, wetlands, and other coastal environments. It is estimated that approximately one-third of all Navy landfills have groundwater infiltrating the waste (Chadwick, Kito, Carlson, and Harre, 2003a). There is a general requirement to determine if contaminants from these sites are migrating into marine and surface water systems at levels that could pose a threat to the environment.

Currently, these problems are evaluated by the use of hydraulic head measurement in shore-side wells and/or numerical models that provide theoretical predictions of flow and contaminant migration. However, these measurements and models are of limited utility in areas adjacent to marine systems where tides, waves, and strong density gradients make

it difficult to establish boundary conditions. In addition, current techniques for verifying the model predictions are inadequate.

Historically, two major obstacles in studying groundwater exchange have been (1) identifying the spatial location where exchange is likely to take place, and (2) accurately measuring the groundwater seepage across the sediment-water interface. Early progress in the development of technology for quantifying seepage into surface waters was made by Lee (1977).

This technology involves a device consisting of a cut-off section of a 55-gallon drum (area 0.255 m^2) in which the open end is inserted into the sediment. Attached to the drum via an outflow port is a 4-L plastic bag that collects the seepage. The volume of the bag and sampling interval are recorded and the specific discharge is obtained by dividing the volume of collected seepage by the area of the drum.

Although generally quite effective, various errors have been associated with the device that must be corrected for prior to sampling (Shaw and Prepas, 1989; Belanger and Montgomery, 1992). Another disadvantage to this method is that it is quite labor intensive since the plastic bags need to be monitored and replaced continuously.

Cherkauer and McBride (1988) overcame some of these shortcomings by designing a remotely operated seepage meter. Plastic collection bags were used, but separate chambers were installed so that samples could be collected remotely. In addition, this meter did not require manual installation, but rather it was heavy enough so that it sank into the bottom sediment as it was lowered. The major drawback to this seepage meter was that with a weight of >150 pounds, it was not very portable, could only be used in large water bodies, and might distort flow paths slightly as it was sealed into the bottom.

Further advancement of the Lee (1977) technique came from Chadwick et al (1999). Their meter consists of a Lee-type meter with a six-position selector valve that allowed programmable, automated measurements of up to six seepage samples over a single deployment period (Figure 1-2). Attached to each outlet of the selector valve was a plastic collection bag that collects seepage over a specified time interval. This system provided some of the first automated quantification of seepage related to tidal forcing.

A major advance in quantifying transient seepage came from Taniguchi and Fukuo (1993). The flow measurement in this seepage meter was based on a thermal perturbation technique and has the capability to continuously record specific discharge. Although divers are still needed, the deployment and measurement of seepage is much less labor intensive than previous methods. This represented the first meter that did not depend on bags to quantify seepage, and provided a capability for continuous measurement rather than the discrete quantification provided by the Lee-type meter and its variations.

More recently, Paulsen et al. (2001) developed an improved continuous-measuring seepage meter using a time-transient ultrasonic flow-sensing technique. The seepage meter uses two piezoelectric transducers to continuously measure the travel times of ultrasonic waves. As water enters the flow tube, it passes through the ultrasonic beam path. The ultrasonic signal that travels with the flow will have a shorter travel time than the signal traveling against flow.

The perturbation of travel time is directly proportional to the velocity of flow in the tube. The flow tube is connected to a data logger that records both incremental and cumulative discharge simultaneously (Figure 1-3). The ultrasonic flow meter can detect reversals of flow such as a negative groundwater flux in which the overlying surface water is recharging the seepage zone. An example data set of specific discharge into West Neck Bay, Shelter Island, New York, using the ultrasonic seepage meter is shown in Figure 1-4.

Following a review of existing technologies (Chadwick et al., 2003a), the Navy's Pollution Abatement Ashore (0817) program (Naval Facilities Engineering Command [NFESC]) sponsored the development of new monitoring methodologies to augment and validate models for groundwater fate and transport at these sites, and to determine the extent of the waste site's contribution to a particular waterway, bay, or estuary. A series of technologies were investigated for their applicability toward direct quantification of coastal contaminant migration via groundwater, and two prototypes were developed (Chadwick et al., 2003b).

The technologies include a screening probe for determining where groundwater may be discharging (the Trident probe, Figure 1-5), and an integrated seepage meter and water sampling system (the UltraSeep, Figure 1-6) for quantifying discharge rates and chemical loading. The Trident probe is a combined conductivity sensor, porewater sampler, and temperature sensor probe that utilizes salinity, temperature, and chemical contrasts between groundwater and surface water to map areas of potential groundwater discharge. The UltraSeep system is an integrated ultrasonic seepage meter and water sampling system for quantifying discharge rates and chemical loading from groundwater flow to coastal waters.

The prototype models of the Trident probe and UltraSeep have been successfully field tested at the Anacostia River (District of Columbia), Eagle Harbor (Washington), North Island Air Station (California), and Pearl Harbor (Hawaii). Based on the extensive data gathered in those prototype demonstrations, the technology has been further developed in a form that can be made commercially available. This project will provide the first opportunity to field test the newly commercialized instruments.

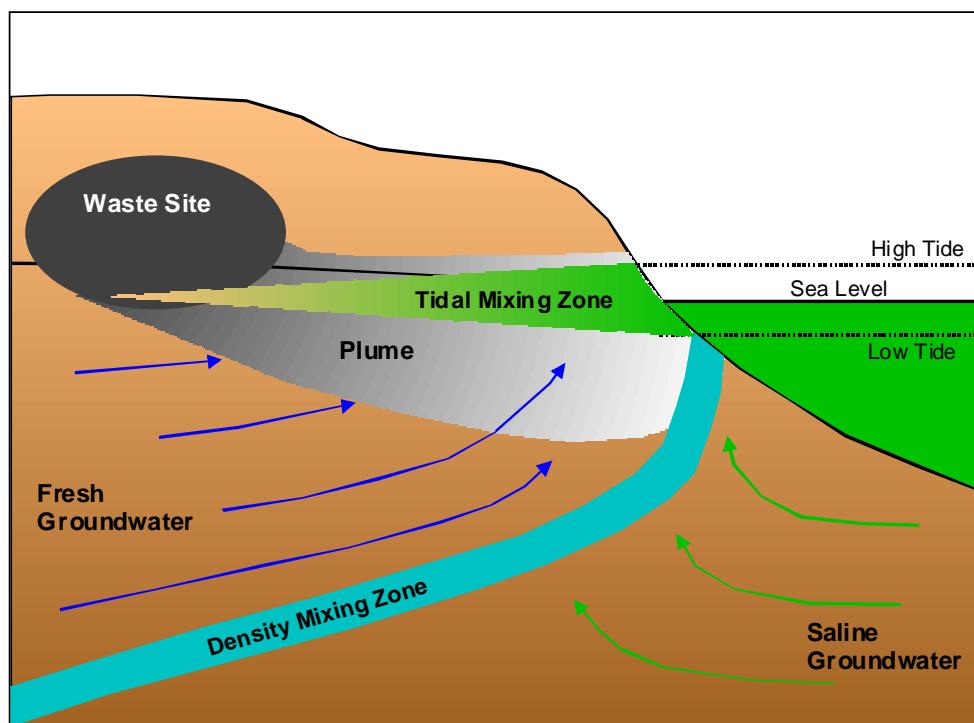


Figure 1-1. Conceptual representation of the coastal contaminant migration process and associated groundwater-surface water interaction.

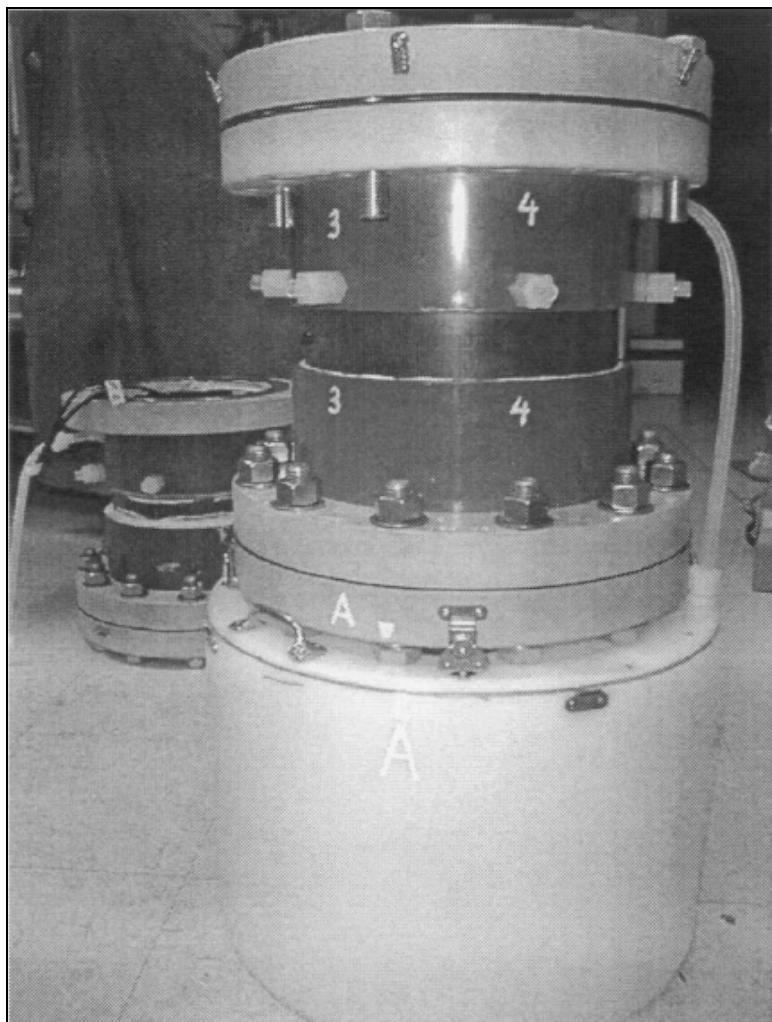


Figure 1-2. Seepage meter utilizing automated collection bag measurements
(Chadwick et al., 1999).

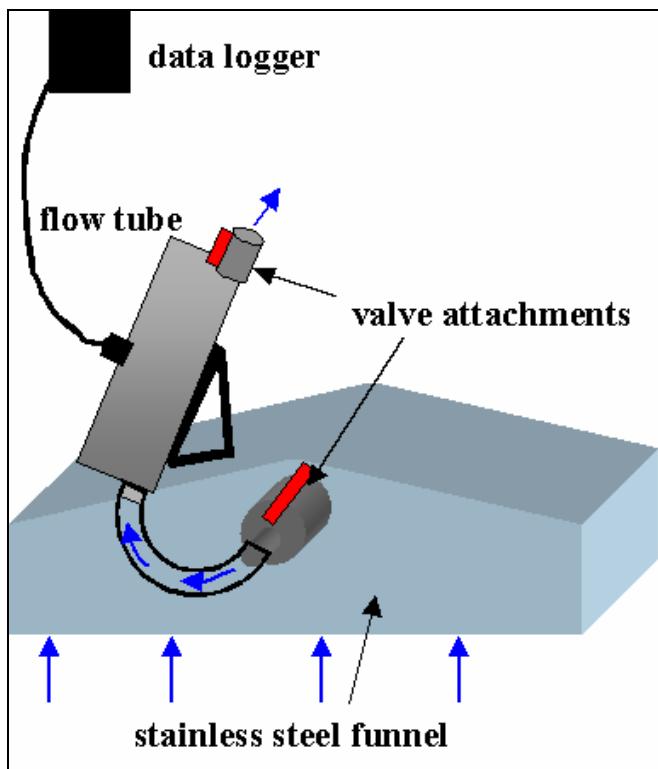


Figure 1-3. Field deployment of ultrasonic seepage meter (not to scale).

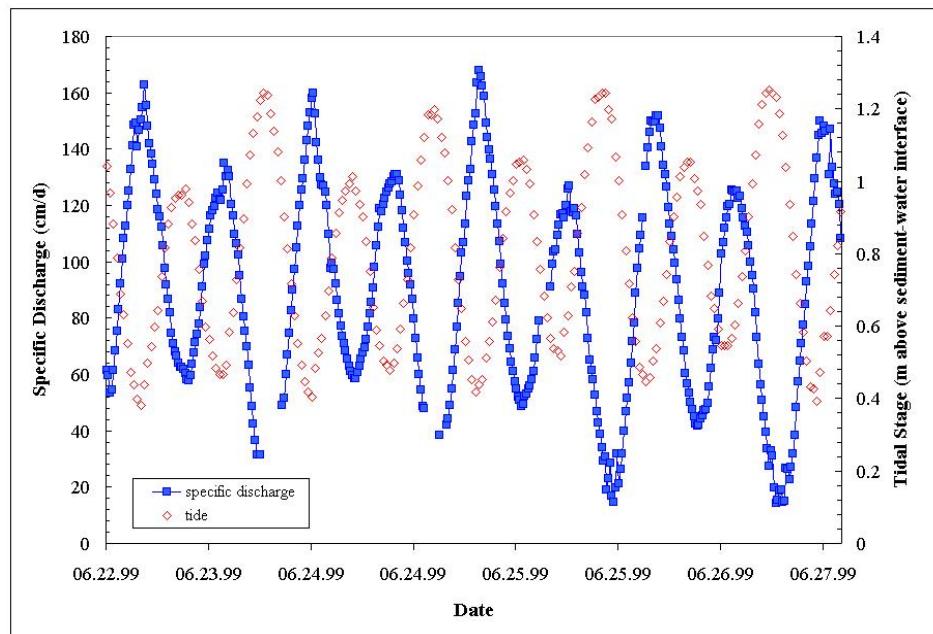


Figure 1-4. Example data set of specific discharge recorded using the ultrasonic seepage meter collected from West Neck Bay, Shelter Island, NY; sampling interval = 15 minutes.

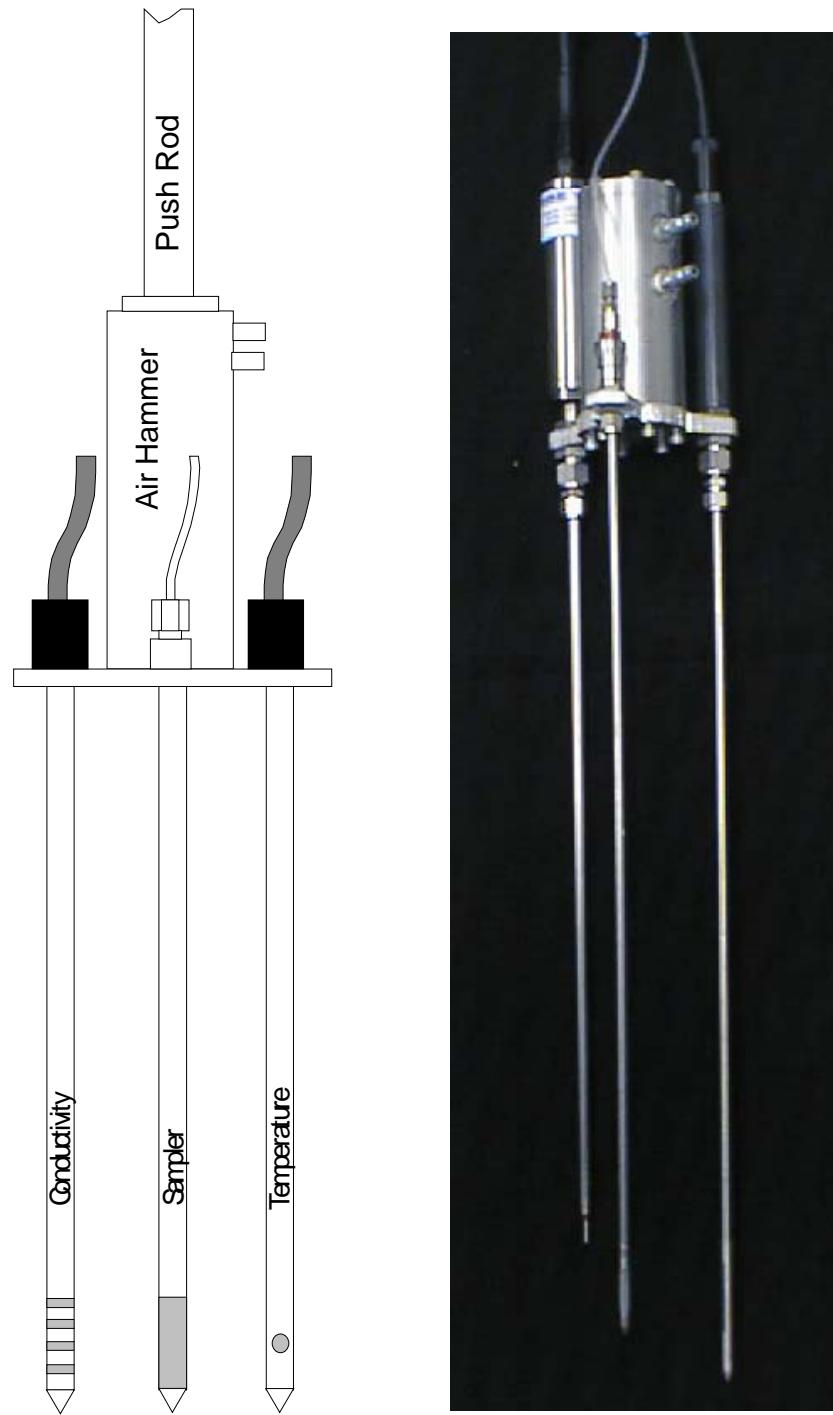


Figure 1-5. Schematic and photograph of Trident probe showing conductivity, temperature, and water sampling probes.

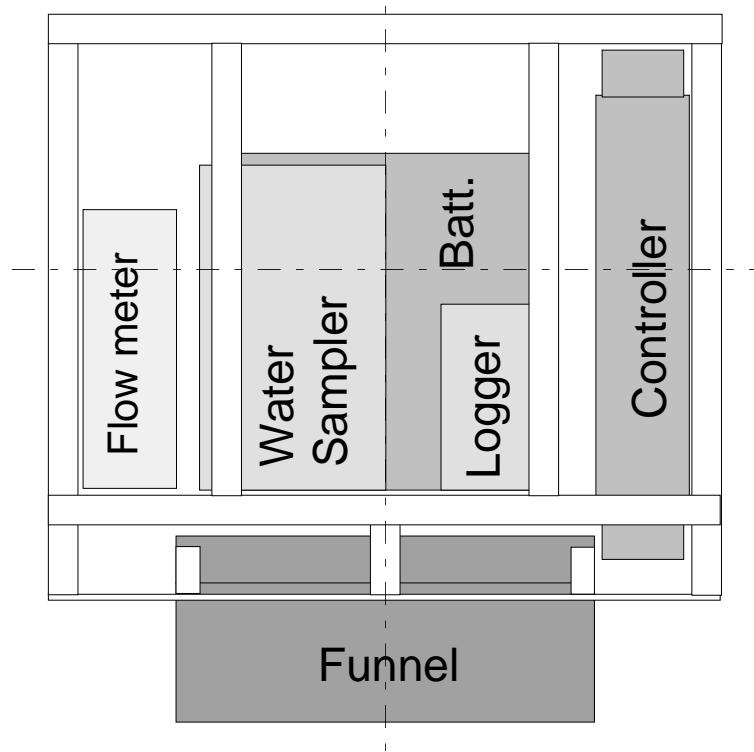
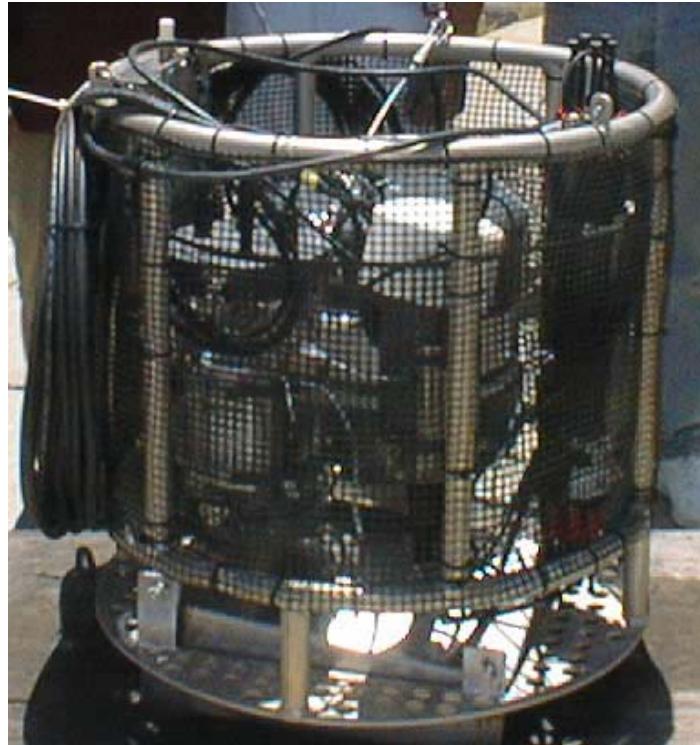


Figure 1-6. Photograph and schematic of UltraSeep meter.

1.2 OBJECTIVES OF THE DEMONSTRATION

The overall objective of this project is to field demonstrate and evaluate the effectiveness of two technologies for characterizing coastal contaminant migration. The technologies include recently commercialized versions of a screening probe for determining where groundwater may be discharging, and an integrated seepage meter and water sampling system for quantifying discharge rates and chemical loading:

- Trident Probe—A combined conductivity sensor, porewater sampler, and temperature sensor system that utilizes salinity, temperature, and chemical contrasts between groundwater and surface water to map areas of potential groundwater discharge.
- UltraSeep—An integrated ultrasonic seepage meter and water sampling system for quantifying discharge rates and chemical loading from groundwater flow to coastal waters.

The purpose of this demonstration is to perform a full-scale technology evaluation in the field using the Trident probe and the UltraSeep. The technologies will be demonstrated in offshore areas adjacent to known historical landfills or hazardous waste sites where there is documented evidence of potential contaminant migration to the surface water. The demonstration will be performed at two locations: Naval Support Activity (NSA) Panama City, Panama City, Florida, and a second site to be determined. The primary contaminant of concern at Area of Concern 1 (AOC 1) NSA Panama City is 1,1-DCE, which has been detected at concentrations exceeding the surface water cleanup target level along the shoreline of St Andrews Bay at 10 to 30 ft below ground surface (Jordon, 1987; Southern Division Naval Facilities Engineering Command, 2002; Southern Division Naval Facilities Engineering Command, 2004). Based on site conditions, it is uncertain whether the 1,1-DCE is entering the bay. The specific objectives of this field effort are to perform the following:

- Demonstrate that the Trident probe can be used to help delineate areas where groundwater seepage is occurring and CoC concentrations in those areas
- Demonstrate that the UltraSeep system can be used to quantify the flow of groundwater and concentration of contaminants that may be impinging on the surface water system
- Demonstrate the technology to end-users to determine the utility of these tools for making decisions at DoD coastal landfills and hazardous waste sites
- Quantify costs associated with the operation of each of the technologies

In order to demonstrate the Trident probe in the field (Objective 1), a grid of stations is established in the area offshore from the suspected groundwater plume. Because the Trident probe relies on contrast in temperature and/or salinity to identify groundwater discharge, it is important to apply the technology in areas where this contrast is present. The Trident probe is then deployed over the sampling grid, and the temperature and conductivity characteristics of the study area are mapped. At the same time, the water sampler on the Trident probe is used to collect water samples for analysis of contaminants. Contaminant analysis may be carried out on-site, or at a traditional laboratory.

Areas of groundwater discharge are generally characterized by stronger thermal and/or saline contrast. These are also the areas where groundwater-borne contaminants are most likely to be encountered. Thus, demonstration of the Trident probe would be considered successful if on the one hand, a strong discharge area was isolated, and the contaminant plume was found in the same region. Alternatively, the groundwater discharge may be highly

dispersed before reaching the surface water. In this case, the Trident probe should indicate very weak or no contrast, and the contaminant levels should be significantly attenuated relative to the onshore levels. Detailed criteria for demonstration of the Trident probe are described in Section 4.

For the UltraSeep demonstration (Objective 2), a minimum of three stations will be identified for evaluation based on the Trident probe survey. The stations will represent a gradation in the expected level of groundwater discharge at the site. The UltraSeep will be deployed at these stations over a complete tidal cycle during which groundwater discharge/recharge rates will be measured, and discharge samples will be collected. Samples will be characterized for groundwater-borne contaminants to determine if the contaminants are discharging into the surface water. If successful, the UltraSeep should provide a quantitative assessment of the rate of groundwater discharge to the surface water, and if present, the associated contaminant loading. The system should also be capable of distinguishing between areas of low and high discharge, and areas where contaminants are present or not present. Detailed criteria for demonstration of the UltraSeep are described in Section 4.

Another important aspect of the field demonstrations is to provide an opportunity for end-users to become familiar with the technology so that it can be used with confidence in regulatory projects (Objective 3). For this reason, the demonstration has been integrated directly into the Corrective Measures Study for NSA Panama City. The Trident probe and UltraSeep technologies will be used to assess the viability of Monitored Natural Attenuation (MNA) as a corrective measure at the site. Thus, the work performed under the demonstration will be an integral part of the regulatory program and will receive full review and evaluation for the practical application of the technologies to the site.

By demonstrating the Trident probe and UltraSeep at a site where the results will be applied to site decisions, the technology will be transferred to this end-user in a way that is practical. The site results and reports will also help transfer this technology to other end-users as it will clearly demonstrate the potential value for decision making at many coastal sites. Regulatory partnering will include site regulators, the California Environmental Protection Agency (Cal/EPA) Department of Toxic Substances Control, and the Interstate Technology Regulatory Cooperation (ITRC). Cal/EPA will formally review and comment on the proposed technical approach, observe field operations, and review the data collected for the Trident probe and UltraSeep demonstrations through the Cal/EPA Hazardous Waste Technology Demonstration Program.

Finally, the field demonstrations will provide an opportunity to rigorously document the costs associated with application of the technology (Objective 4). This aspect of the demonstration is important from the standpoint that use of the technology at a given site must be weighed against other options to determine its cost-effectiveness. A detailed analysis of costs will provide the site manager with the required data to make informed decisions about assessment and restoration options.

1.3 REGULATORY DRIVERS

Concerns over contaminants moving from groundwater to surface water are found at sites being regulated under both the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA). State and federally regulated sites often have to meet levels such as a Maximum Contaminant Level (MCL) at a point of compliance in order to conservatively protect surface water.

In many cases, groundwater in shoreline wells must meet surface water Applicable or Relevant and Appropriate Requirements (ARARs) due to a lack of information or uncertainty regarding modeled dilution and attenuation factors. By making direct measurements at the point where groundwater enters surface water, decisions can be made based on specific data rather than on uncertain models or a measurement at a conservative point of compliance.

The first demonstration site at NSA Panama City AOC 1 is an example of this type of regulatory driver. There is an exceedance of the Surface Water Cleanup Target Level (SWCTL) at which this RCRA site is regulated for 1,1-DCE. The samples used for this determination were taken at shoreline wells located between about 30 to 300 ft inland, where groundwater is 10 to 30 ft below ground surface. Based on the level of contamination and the hydrogeology of the site, it is possible that with direct measurements in the sediments the SWCTL for 1,1-DCE may not be exceeded at the groundwater–surface water interface. This would allow consideration of MNA as a corrective action, which could result in significant cost savings for the site.

The second demonstration site at NTC Orlando also fell under this type of regulatory driver. The remedial investigation (RI) and baseline risk assessment for OU 4 identified no unacceptable human health risks for soil, surface water, or sediment, and no ecological risks for any media. However, elevated levels of PCE and its degradation products were found in ground and surface waters. The baseline risk assessment identified an unacceptable human health risk based on the assumption that a potable water supply would be developed in the contaminated portion of the surficial aquifer.

Therefore, risk-based remedial action objectives (RAOs) were developed to protect humans from possible future risks resulting from potable water exposure to contaminants currently present in the surficial aquifer groundwater. According to the Draft Record of Decision (ROD) (Tetra Tech NU.S. [TtNU.S.], 2001), the RAOs for a non-residential future use of the site are as follows:

- RAO 1: Reduce the potential for human ingestion of groundwater containing contaminants of concern (CoCs) that exceed drinking water-based regulatory requirements or risk-based acceptable exposure levels.
- RAO 2: Gain control over groundwater migration of volatile organic compounds (VOCs) concentrations that contribute to exceedances of Florida Department of Environmental Protection (FDEP) surface water standards to Druid Lake.

1.4 STAKEHOLDERS-END-USER ISSUES

DoD Remedial Project Managers (RPMs) require improved monitoring methodologies to augment and validate models for groundwater fate and transport at these sites, and determine the extent of the waste site's contribution to a particular waterway, bay, river or estuary. The Trident probe, which carries conductivity and temperature sensors and a porewater sampler, was developed to screen sites for areas where groundwater discharges to a bay, river, or estuary. The resulting survey data are used to determine deployment locations where the UltraSeep meter can be utilized for long-term measuring and sampling. Using this information, the maximum extent of groundwater contaminant flux into a bay or estuary can be accurately determined.

In 2003, Naval Facilities Engineering Command (NAVFAC) provided a hypothetical scenario where this technology could result in significant cost savings: A chlorinated groundwater plume is migrating towards a surface water body. The site has been

conservatively modeled and the concentrations exceed the MCL at the point of compliance. The modelers are not allowed to account for any natural attenuation that may be occurring at the site. An innovative remedy is selected to remediate the site such as in situ anaerobic bioremediation.

The approximate average cost per site for the application of this technology is \$500K. The groundwater at this site is entering the surface water body through a humic layer composed of detritus. Sampling revealed that the concentration entering the surface water body is below the MCL due to reduction occurring in the humic layer. The total cost of sampling is \$100K, which would save approximately \$400K.

The primary stakeholder/end-user for the NTC Orlando demonstration was the Base Realignment and Closure (BRAC) cleanup team called the Orlando Partnering Team (OPT), including Southern Division Naval Facilities Engineering Command, the U.S. Environmental Protection Agency (U.S. EPA), and the FDEP.

Prior to commencement of the demonstration, members of the OPT reviewed the demonstration plan, and the PI briefed the OPT on the elements of the plan. OPT concerns were focused on whether the site could be transitioned from an active pump and treat system, to monitored natural recovery, depending on risk levels associated with exposure in the surface waters of Lake Druid.

OPT identified the primary technical design issue, which was a concern to extend the sampling closer to shore within a shallow vegetated zone, where historical sampling suggested potential release to surface water and exposure risk to waders might be most likely. The sampling design was adjusted to accommodate this concern by including an eight additional Trident probe stations within this zone, along with the original 24 stations, resulting in a total of 32 stations for the demonstration.

2. TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY DEVELOPMENT AND APPLICATION

The technologies to be demonstrated include recently commercialized versions of a screening probe for determining where groundwater may be discharging (the Trident probe, Figure 2-1), and an integrated seepage meter and water sampling system for quantifying discharge rates and chemical loading (the UltraSeep). The commercial versions of the technologies were produced by the Oceanscience Group of Carlsbad, California, in cooperation with Zebra-Tech Ltd., Nelson, New Zealand. Detailed operational manuals for the commercial systems are included in Appendix A.

2.1.1 Trident Probe

The Trident probe is a direct-push, integrated temperature sensor, conductivity sensor, and porewater sampler developed to screen sites for areas where groundwater may be discharging to a surface water body (Chadwick et al., 2003b). Differences in observed conductivity and temperature indicate areas where groundwater discharge is occurring. The integral porewater sampler can be used to rapidly confirm the presence of freshwater or other chemical constituents.

The temperature sensor consists of a ruggedized digital oceanographic thermometer embedded near the tip of a 90-cm long stainless steel probe (Figures 2-2 and 2-3). The sensor has a measurement range of -5 to +45 °C at an accuracy of <0.1 °C, and a resolution of 0.001 °C. The sensor response time is about 60 s.

The conductivity probe utilizes a small-diameter, stainless steel, alternating current (AC)-excitation 3-electrode sensor installed at the tip of the same 90-cm probe that houses the temperature sensor. The conductivity sensor has a range of 0 to 80 mS/cm, an accuracy of <2% of the calibrated range, and a resolution of 0.01 mS/cm. The conductivity signal varies primarily as a function of changes in salinity, and secondarily as a function of clay content and porosity (Figure 2-4).

A reference conductivity and temperature sensor is mounted on the instrument frame to provide a direct comparison of the overlying surface water conditions with the interstitial water conditions (contrast). For the temperature sensor, areas of groundwater seepage may appear either as warm or cold in contrast to the surface water, depending on the seasonal and site characteristics. For the conductivity sensor, areas of likely groundwater seepage are generally associated with low conductivity, as a result of low salinity, low clay content (high permeability), or both.

Both sensors are coupled through an underwater connector and cable to a deck unit that integrates the probe and reference temperature and conductivity signals with the signal from a Global Positioning System (GPS) sensor mounted on the top of the push-pole (Figures 2-1 and 2-4). The GPS is a Garmin® Model 17 with a stated accuracy of <15 m in standard mode, and <3 m in Wide-Area Augmentation System (WAAS) mode. The integrated data stream from the deck unit is sent to a laptop via RS-232. The laptop is used to apply calibration and temperature corrections to the signals, and record and display the results (Figure 2-5).

The water sampling probe allows interstitial waters to be extracted from the sediment at selected depths up to about 90 cm below the sediment water interface. Porewater is collected by syringe or vacuum pump extraction through a small-diameter, Teflon®-coated, stainless steel probe (Figures 2-2 and 2-3). The probes consist of a length of 95-mm-diameter stainless

steel tubing fitted with a solid removable point. On the side of the tube near the tip, there is a sample port consisting of a hole covered by a small mesh size (250 µm) stainless steel screen. The screen section is easily removable for cleaning or replacement, if required (Figure 2-3).

The two probes are collocated with a spacing of about 20 cm on an aluminum mounting-base (Figure 2-2). Coupled to the mounting base is a submersible air hammer (not shown) that can be used to assist in driving the probe into the sediment. On the top of the air hammer is a coupling for a 2-m aluminum push rod that can be sequentially lengthened in 2-m increments to a about 10 m. A bundled cable including the temperature and conductivity signals, Teflon® sampling tube, and pneumatic air-hammer hose runs from the probe to the surface.

A Trident probe survey is conducted by inserting the probe into the seabed (seabed is used here to mean the bottom of the ocean, estuary, or bay) from a small boat. The Trident probe has an integral hydraulic hammer to assist in penetrating harder beds. The resulting survey data are used to develop spatial maps indicating areas where groundwater may be discharging, and to determine locations for deployment of the UltraSeep meter for longer term measuring and water sampling.

In operation, the Trident probe can be deployed in several ways, depending primarily on the depth of the site (Figure 2-6). In very shallow water (0 to 1 m), the operator simply walks or wades to a sampling station, and manually pushes the probe to the desired depth. This is the expected method for the NSA Panama City demonstration. Experience has shown that the probe pushes easily by hand to a depth of about 30 cm. The air hammer, or a slide hammer, can then be used to complete the push, if necessary. In water of moderate depths (1 to 10 m), the probe is easily deployed from a small boat using the push rod in combination with the air hammer (Figure 2-7). It is important that the boat be well anchored to minimize lateral loading on the probe during the insertion. In deeper water (>10 m), the probe can be deployed by diver (Figure 2-8) or be attached to a landing frame.

Once on station with the probe inserted, data are collected from the conductivity and temperature sensors using the TridentTalk software (Figure 2-9, Appendix A). The software displays the probe and reference temperature and conductivity signals, along with the GPS position. The software also automatically calculates and displays the probe vs. reference temperature and conductivity contrast. Once the sensor readings have stabilized, the data are recorded by activating the “Log current data” button on the TridentTalk display. The data can then be reviewed in numeric format, or displayed spatially using the Advanced Ground Information Systems (AGIS) graphical information system software (Appendix A). The spatial AGIS display provides a capability for rapidly evaluating the most likely areas of groundwater discharge based on temperature and conductivity contrast.

2.1.2 UltraSeep

The UltraSeep system is an integrated seepage meter and water sampling system for quantifying discharge rates and chemical loading from groundwater flow to coastal waters. Traditional seepage technology was modified and improved to include automated multiple sample collection and continuous flow detection with ultrasonic flow meters. The resultant instrument, the UltraSeep, makes direct measurements of advective flux and contaminant concentration at a particular location (Chadwick et al., 2003b). The data produced are time series, over tidal cycles, of groundwater flow, contaminant concentration, and associated sensor data, which allow an accurate determination of the presence or absence of groundwater flow and associated contaminant flux from a terrestrial site into a bay or estuary.

The commercial version of the UltraSeep meter combines the continuous direct measurement of groundwater seepage rates using the time-transient ultrasonic technique described by Paulsen et al. (2002), with a multi-sample water sampling system (Figure 2-10). The meter relies on a Teflon®-coated, stainless steel, open-bottomed chamber measuring 50 cm in diameter to funnel the seepage water to the flow sensor. The flow sensor is connected to the funnel via 12-mm Teflon® tubing, allowing free flow of water between the funnel and the outside environment.

Data from the flow meter and a temperature/conductivity sensor housed within the funnel are monitored by an integrated data logger/controller unit (DLC). Based on the measured flow conditions, the controller activates a water sampling system that can pump water to up to 10 sequential sampling bags mounted around the meter's perimeter. All of these components, along with a 12-V submersible battery housing, are mounted within a 72-cm-diameter by 58-cm high cylindrical stainless steel frame (Figure 2-11).

The ultrasonic flow sensor (Figure 2-12) uses two piezoelectric transducers to continuously measure the travel times of ultrasonic waves along the flow path of the seepage water through the flow tube (Figure 1-6). As water enters the flow tube, it passes through the ultrasonic beam path. The ultrasonic signal that travels with the flow has a shorter travel time than the signal traveling against flow. The perturbation of travel time is directly proportional to the velocity of flow in the tube. The flow sensor sensitivity is about $1.5 \text{ cm}^3/\text{min}$, which given the amplification from the funnel, translates to a seepage rate of less than 1 cm/d. This sensitivity can be further improved by signal averaging.

The DLC (Figure 2-12) provides the primary data logging and control functions for the UltraSeep meter. The DLC allows programmable logging and control via analog, digital, and RS-232 signals. For the UltraSeep system, the flow sensor data are recorded as an RS-232 signal. Typically, the control program evaluates this signal for a 5-minute averaging time, and based on the laboratory flow calibration, determines the current seepage rate. If the seepage rate is positive, the DLC activates the water sampler pump, and sets the pumping rate at the current seepage rate (Figure 2-14).

After a 5-minute sampling period, the flow signal is again evaluated, and the process is repeated. If necessary, a brief recovery time can also be included in the sequence to allow the flow to re-establish after pumping. At a user-selected time interval, the DLC activates the sampling valve and switches to a new sampling bag. The switching can also be activated based on volume pumped to avoid overfilling the sample bag.

The water sampler consists of a high-accuracy, low-flow rate, peristaltic pump connected in line with a 10-position selector valve (Figure 2-12). Both units are housed within the same submersible pressure case as the DLC, although they are separated from the electronics by a watertight bulkhead. The pump allows sampling at user-specified flow rates ranging from about 0 to $13 \text{ cm}^3/\text{min}$ at steps of $1 \text{ cm}^3/\text{min}$. The selector valve has 10 outlet ports and one inlet port. All water contact parts in the sampling system are constructed from Teflon®, with the exception of the PharMed® pump tubing.

In operation, the UltraSeep meter is lowered to the bottom directly from a boat or by divers using a lift-bag. Once the unit is settled on the bottom, the seal is checked by divers. A period of 2 to 3 hours is generally allowed to ensure that any transient seepage response associated with the deployment activities has dissipated. The unit is then programmed through the SeepTalk interface (Figure 2-13), and the DLC unit then initiates logging and control functions.

At coastal sites, a typical deployment runs over a 12- to 24-hour period to capture an entire semidiurnal or diurnal tidal cycle, although the system can be run continuously for a period of up to about 4 days. During this period, the seepage rate is continuously monitored, and up to 10 water samples are collected for chemical analysis. At the end of the deployment, the meter is recovered using either a lift line to the recovery boat, or by diver assistance.

2.1.3 Technology Development Chronology

Development of the Trident probe and UltraSeep has been ongoing since 2000. The following is a brief overview by year of the technology development.

FY 2000

- Evaluated user needs by defining the number and types of sites, and using a broad team to review available technologies and identify technology gaps
- Published Technology Survey Report

FY 2001

- The technology selection process began by reviewing the technical performance, development status, reliability, and cost of available technologies
- Published Technology Selection Report
- Started technology development and testing of a direct-push screening probe to identify areas where groundwater is released and a seepage meter for groundwater flow and concentration at point of exposure

FY 2002

- Technology development and testing of the Trident probe and UltraSeep continued
- Field demonstrations were conducted at the following sites:
 - Anacostia River: Suspected groundwater migration (with EPA)
 - Eagle Harbor: Cap integrity (with EPA)
 - North Island Naval Air Station: VOC groundwater plume (with Southwest Division [SWDIV])
 - Published Technology Hardware and Protocols Report

FY 2003

- Conducted Pearl Harbor field demonstration in conjunction with a Strategic Environmental Research and Development Program (SERDP)-funded chemical mobility assessment
- Completed Technology Demonstration Report along with numerous presentations and publications as part of technology transfer efforts
- Started commercialization efforts, including hardware development

FY 2004

- Completed initial testing of commercialized technology
- Initiated technology demonstrations under Environmental Security Technology Certification Program (ESTCP)
- Completed initial technology demonstration at NSA Panama City.

2.1.4 Technology Applications

There are three primary application areas for the Trident probe and UltraSeep technologies. These areas include (1) assessment of contaminant discharge to surface water associated with groundwater plumes from terrestrial hazardous waste sites, (2) assessment of contaminant discharge to surface water associated with groundwater leachate from coastal landfills, and (3) assessment of remedy effectiveness for treatment of contaminated groundwater at coastal sites. Other potential applications of the technology include assessment of pore fluid dynamics for contaminated sediments, and evaluation of water budgets for water management applications.

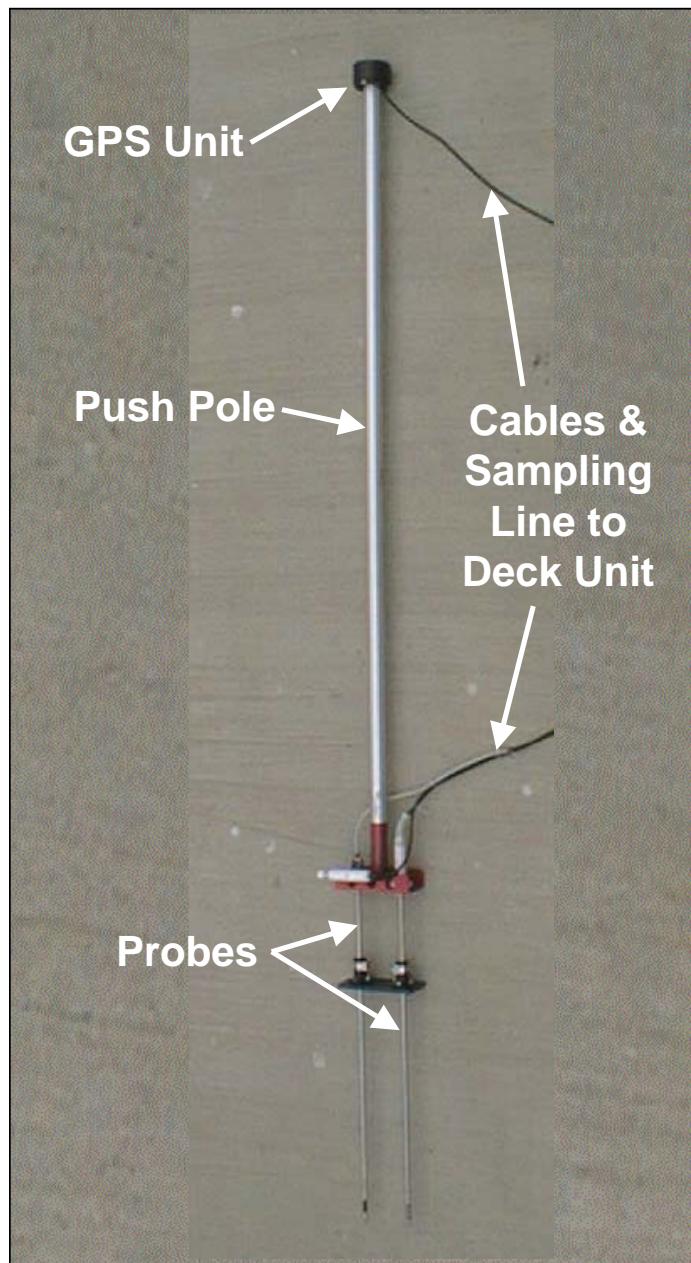


Figure 2-1. Complete Trident probe showing sensor and water sampling probes, push-pole, and GPS unit.

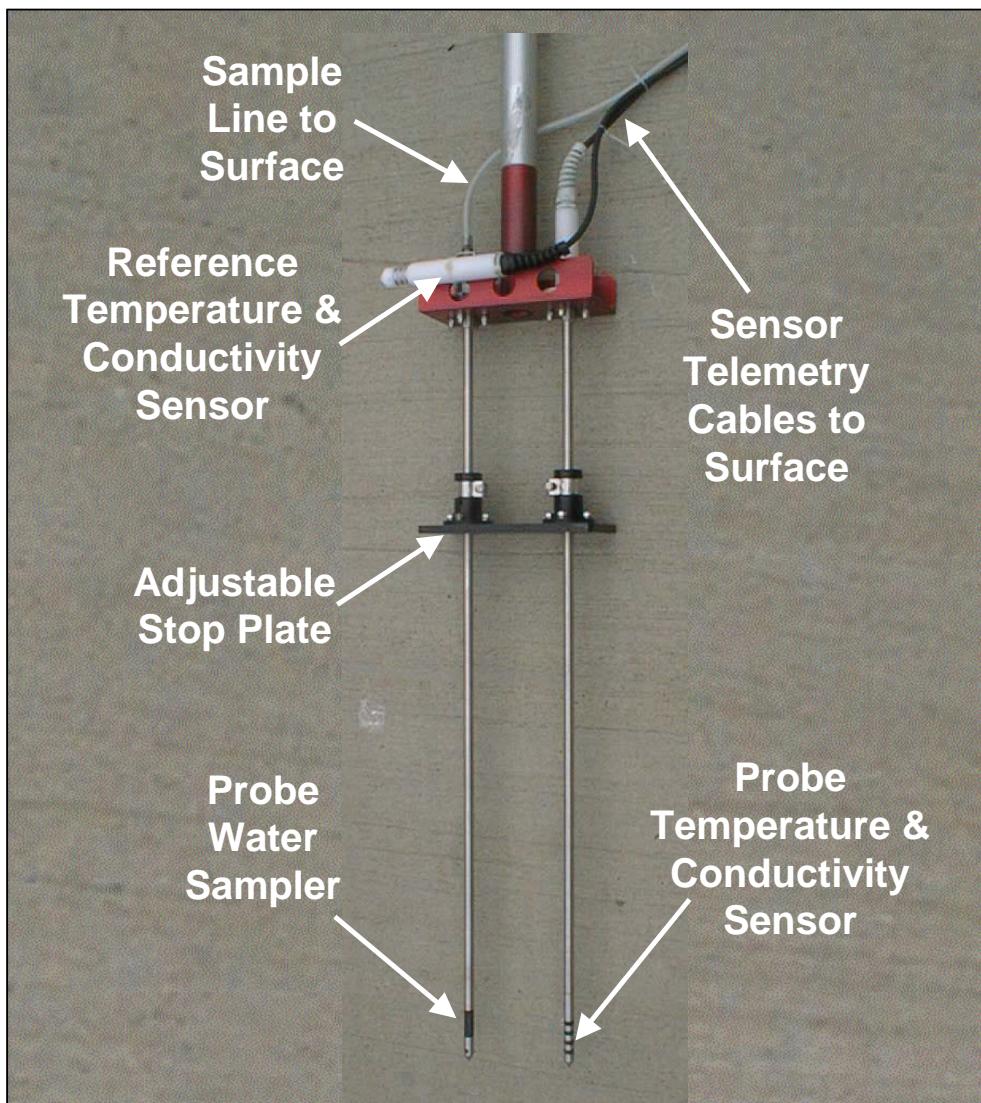


Figure 2-2. Detailed view of Trident probe unit showing mounting of temperature/conductivity probe, water sampling probe, adjustable stop plate, and reference sensor.

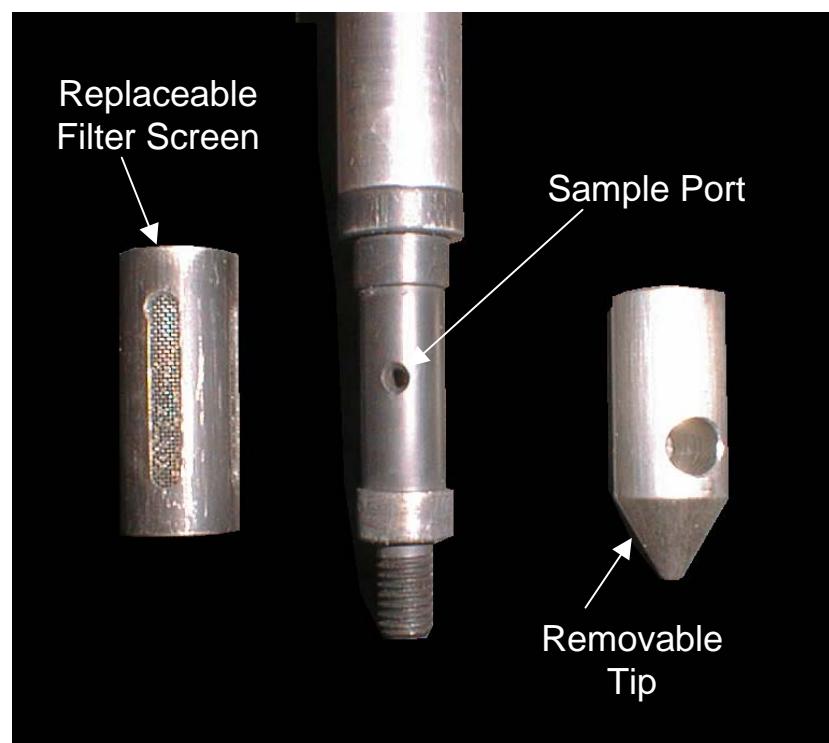
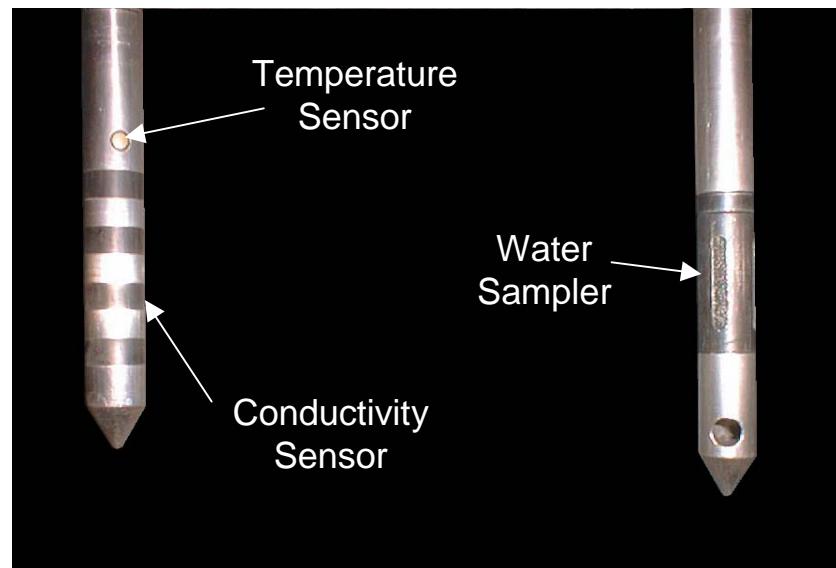


Figure 2-3. Detailed view of Trident probe tips showing embedded temperature sensor button, Wenner-type conductivity probe rings, and screened section of the water sampling probe (above). Bottom image shows disassembled water sampling probe with replaceable filter screen and removable tip.

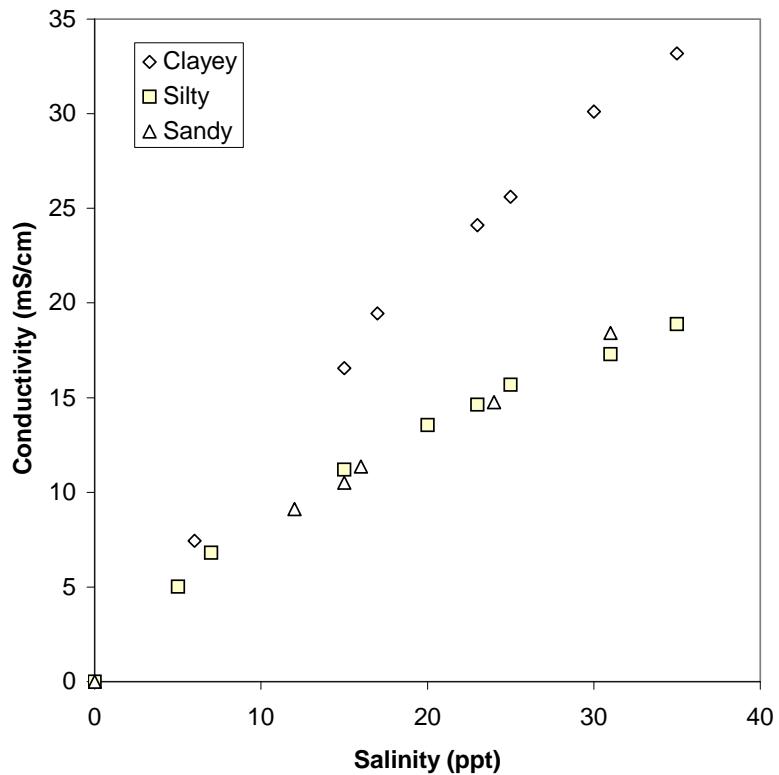


Figure 2-4. Response of Trident probe conductivity probe to changes in salinity and sediment type.



Figure 2-5. Trident probe deck unit interfaced to a laptop. Small gel-cell battery powers Trident probe sensors.

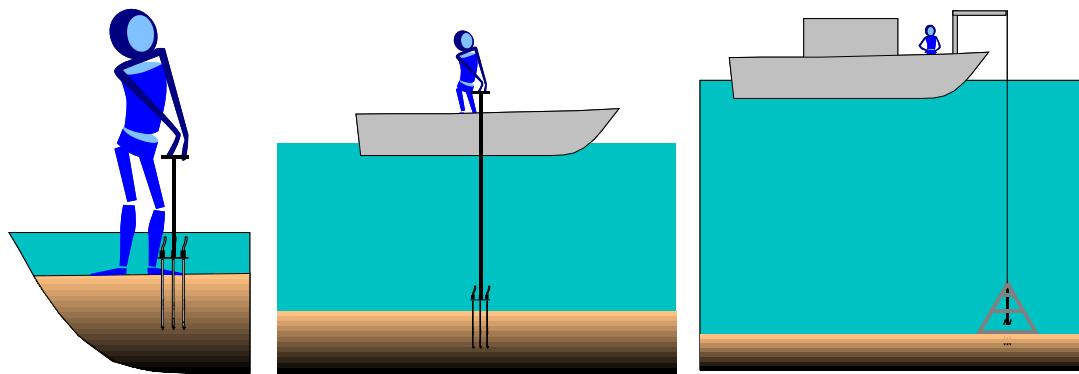


Figure 2-6. (Left to right) shallow-water (0 to 3 ft) push-pole, mid-range (3 to 30 ft) push-pole, and deep-water (>30 ft) deployment methods for Trident probe. Diver method not shown.



Figure 2-7. Deployment of Trident probe from small boat using push-pole and air hammer.



Figure 2-8. Diver using air hammer to deploy Trident probe.

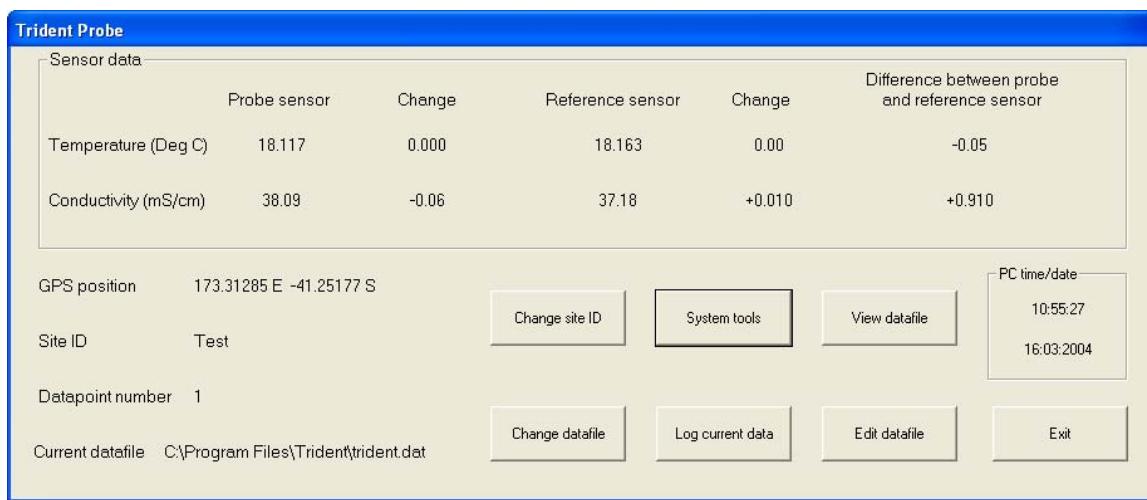


Figure 2-9. Main TridentTalk window.



Figure 2-10. Oceanscience Group commercial UltraSeep system.

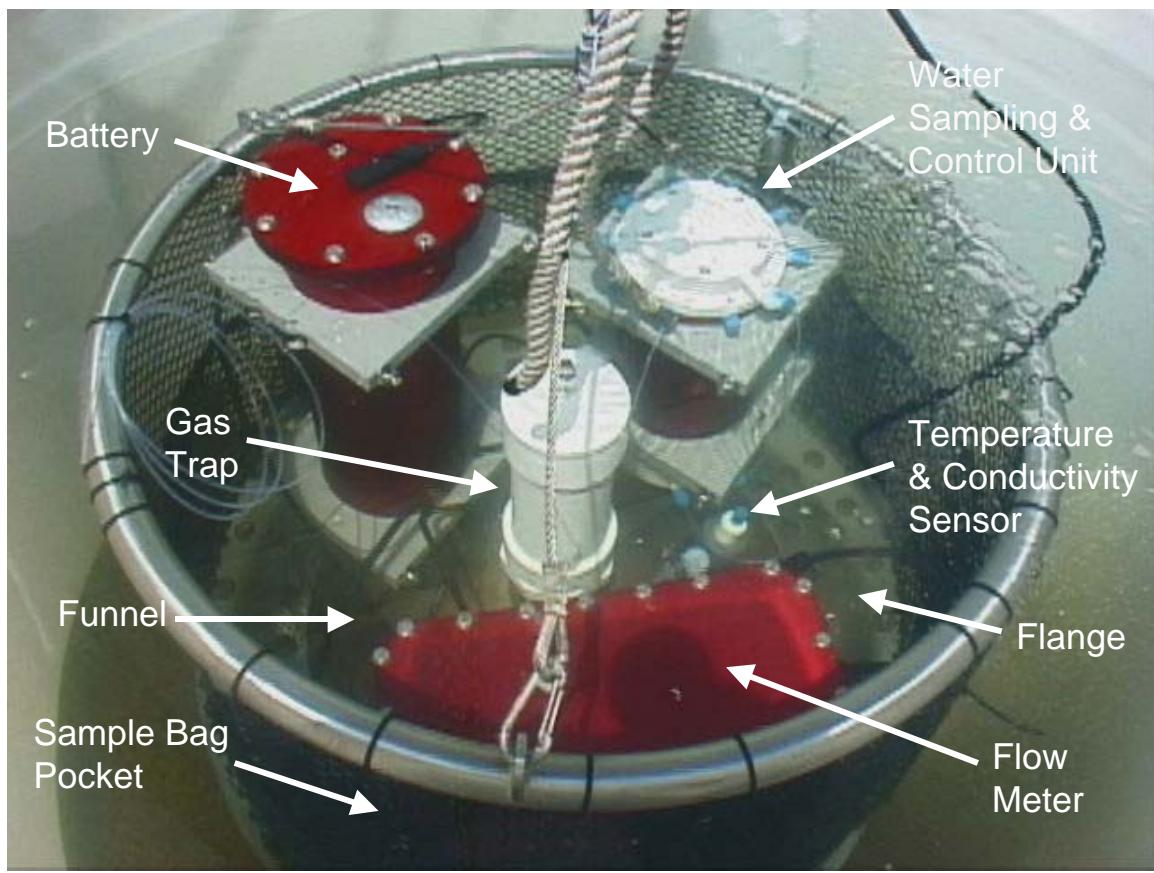


Figure 2-11. Component view of commercial UltraSeep showing the water sampling and control unit, battery housing, flow meter, funnel, gas trap, and sensors.



Figure 2-12. Individual UltraSeep components, including battery (left; shown opened), sampling system and control unit (upper right), and flow meter (lower left).

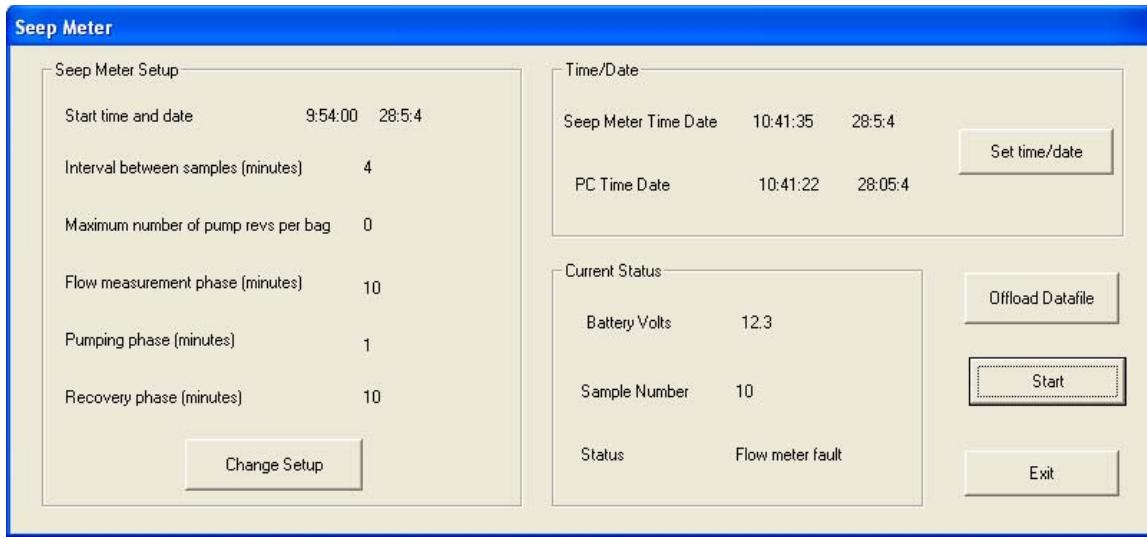


Figure 2-13. Main SeepTalk window.

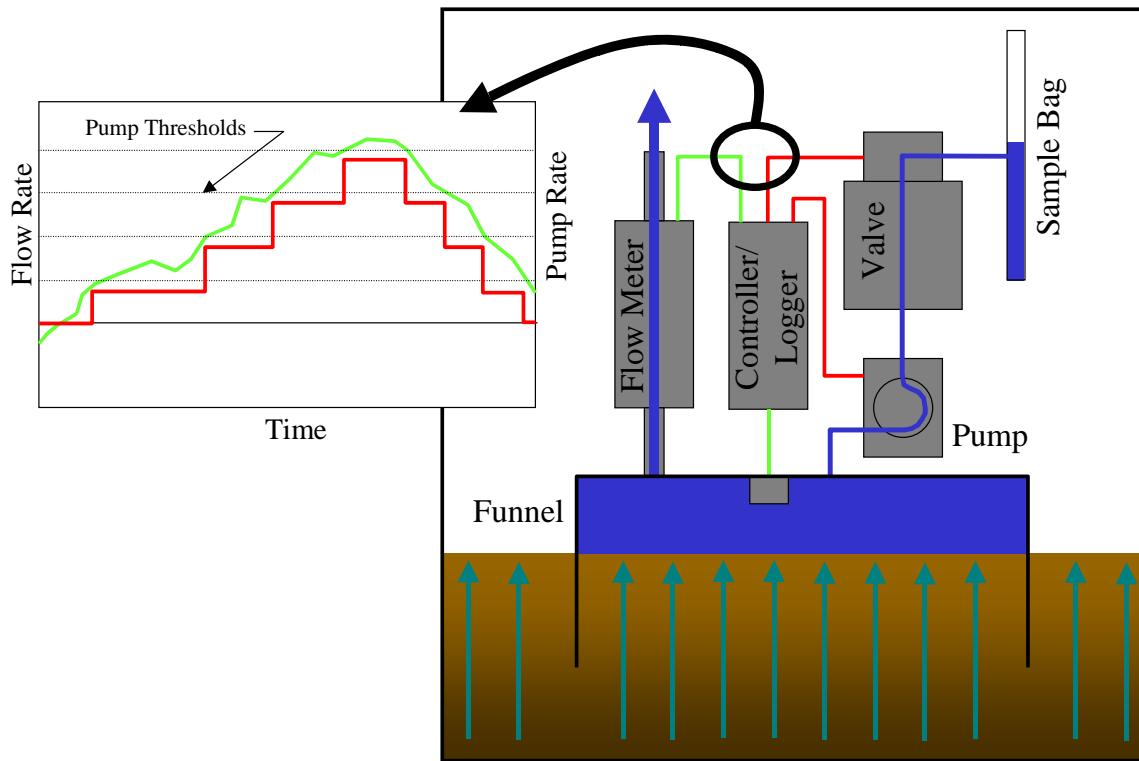


Figure 2-14. Water sampling schematic for UltraSeep system.

2.2 PREVIOUS TESTING OF THE TECHNOLOGY

The Trident probe and UltraSeep have undergone extensive laboratory testing, and have been tested at four field sites. The four field tests represent a range of potential conditions and applications, including assessment of a terrestrial hazardous waste site, remedy effectiveness for a capping system, and pore fluid dynamics for a contaminated sediment site.

2.2.1 Anacostia River

At the Anacostia River demonstration in 2002, contaminated groundwater exchange of PAHs was suspected at several areas along the tidally influenced lower reach of the river. This demonstration was the initial field-testing of the conductivity and porewater probes, and integrated the side-by-side testing of the ultrasonic seepage meter with a traditional seepage meter. Measurements of groundwater seepage and chemistry along the Anacostia River shoreline were made to quantify specific discharge into Anacostia River at six pre-determined stations using a combination of porewater sampling, multi-sample seepage meters, and ultrasonic seepage meters.

Seepage rates were successfully quantified at all six sites (Figure 2-15), while porewater chemistry was obtained at four of the six sites (U.S. EPA 16 Parent PAH Compounds; Figure 2-16). **Error! Reference source not found.** The sites were ranked based on the potential of site groundwater to act as a source or pathway of exposure for PAHs in the river. Several factors were considered, including seepage rates, porewater concentrations, and estimated maximum polynuclear aromatic hydrocarbons (PAH) flux. This demonstration was done in partnership with the U.S. EPA Region 10 and the Anacostia Watershed Toxics Alliance AWTA. See Chadwick et al. (2001)*.

2.2.2 Eagle Harbor

The Eagle Harbor demonstration in 2002 investigated the suspected leakage of a PAH plume through the site capping system. The conductivity and porewater probes were again deployed, and further side-by-side testing of the ultrasonic seepage meter with a traditional seepage meter was done. The demonstration also integrated temperature and conductivity sensors with the ultrasonic seepage meter. Results indicated weak tidal forcing through the capping system**Error! Reference source not found.** (Figure 2-17), with discharging water typically characterized by lower conductivity and temperature than the overlying surface water**Error! Reference source not found.** (Figures 2-18 and 2-19). This project was conducted in partnership with the U.S. Environmental Protection Office (U.S. EPA) Office of Research and Development; Battelle, 2002).

2.2.3 North Island Naval Air Station

The final 2002 demonstration was at North Island Naval Air Station Installation Restoration Site 9. At this site, a known VOC plume was impinging on surface water. The prototype Trident probe and UltraSeep system were deployed there. Full-scale testing of the Trident probe was executed in shallow water mode to evaluate mooring and push protocols. Conductivity and temperature were mapped at approximately a 2-ft depth across a 100-m x 200-m area. Porewater samples were also collected at all stations for salinity and VOCs. This

* Chadwick, D. B., C. N. Katz, J. G. Groves, A. R. Carlson, C. F. Smith, R. J. Paulsen, D. O'Rourke, and N. Gahr. 2001. "Anacostia River Seepage and Porewater Survey Report." Report to the Anacostia Watershed Toxics Alliance. Contact the authors of this report for availability.

mapping revealed areas of VOC seepage into the bay corresponding closely with areas of higher temperature contrast**Error! Reference source not found.****Error! Reference source not found.** (Figures 2-20 and 2-21).

The UltraSeep was subsequently deployed, allowing determination of the tidal relationship to seepage, and the quantification of VOCs released during groundwater discharge**Error!**

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2-22). This demonstration was done with the support of the NAVFAC 0817 program and NAVFAC SWDIV. See Chadwick et al. (1999).

2.2.4 Pearl Harbor

In 2003, the Pearl Harbor field demonstration was conducted in conjunction with an SERDP-funded chemical mobility assessment. The prototype Trident probe and UltraSeep system were successfully deployed at this site to gather data on suspected porewater migration from contaminated sediment. The results were used to compare the rate of transport by porewater advection with other contaminant transport and fate mechanisms, including diffusion, particle transport, and biodegradation (Chadwick et al., 2002b).

2.2.5 Naval Construction Battalion Center Davisville

In 2004, the Trident probe and UltraSeep were used to assess the nature and extent of VOC discharges to surface water in the area offshore from Site 7, Calf Pasture Point, Naval Construction Battalion Center (NCBC) Davisville. Based on the Coastal Contaminant Migration Monitoring assessment, the following conclusions were reached:

1. A region of groundwater discharge in the Entrance Channel with significant VOC concentrations exists along the southern shoreline of Calf Pasture Point in the area previously identified by the shoreline piezometers (Figure 2-23).
2. A secondary region of potential groundwater discharge exists at the northwestern extent of the Entrance Channel study area. However, no VOCs were detected in this area.
3. A large region of groundwater discharge exists in the Inner Harbor to the west of Calf Pasture Point. However, no significant concentrations of VOCs were detected in association with this discharge area. The northern and western extents of this discharge zone were not delineated.

The discharge zones identified are consistent with previous studies and the conceptual model that suggested groundwater discharge toward the south and west from Calf Pasture Point. Significant VOC discharge is currently limited to the near shore zone along the Entrance Channel adjacent to the southern shoreline of Calf Pasture Point. The only action level exceedances were for VC in porewater at two stations All other porewater samples and all of the surface water samples were below the action levels.

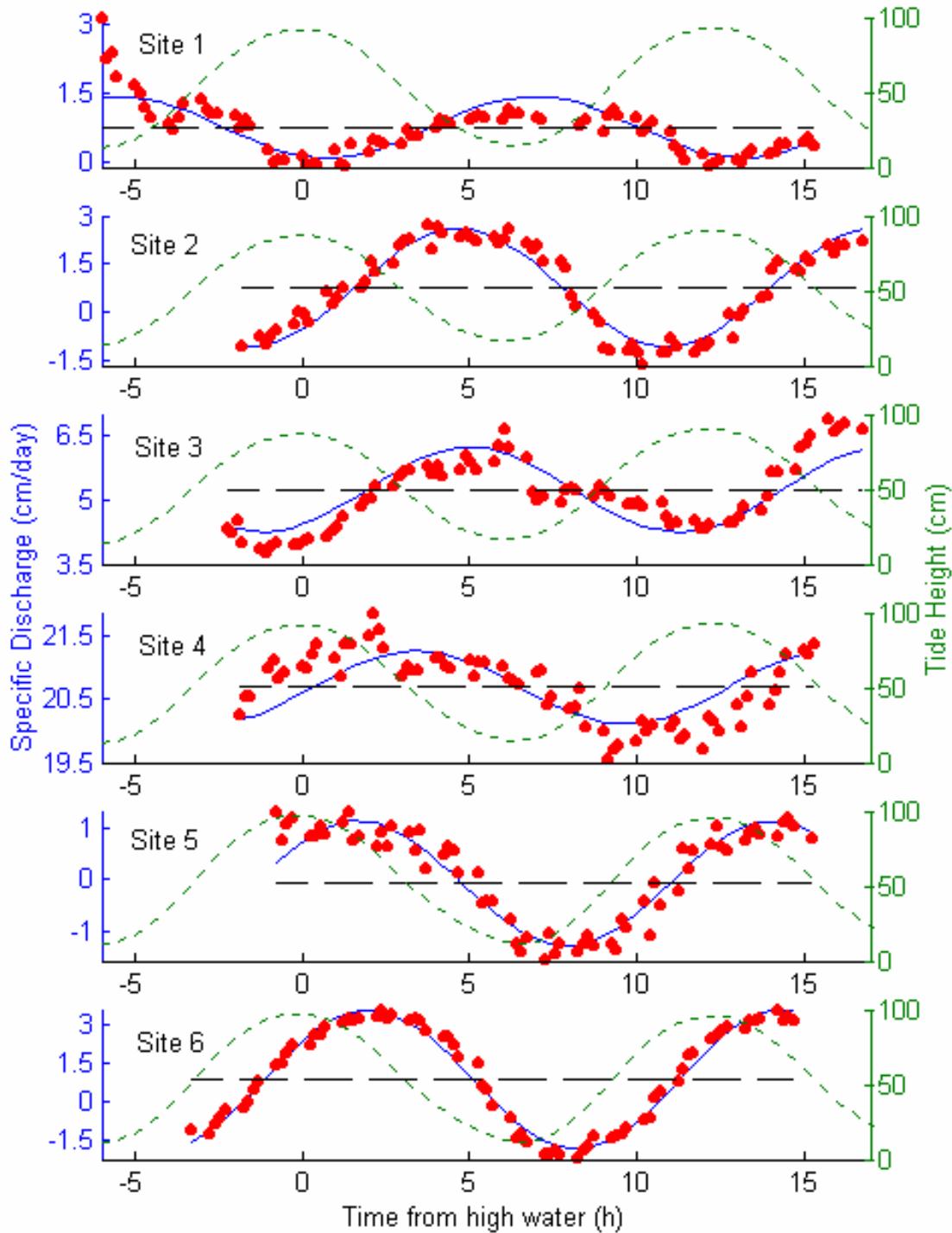


Figure 2-15. Results from the ultrasonic meter deployments at six stations along the Anacostia River. Red dots indicate measured seepage, blue lines are model fit with mean and tidal constituents, the black dashed line is the model fit mean only, and the green dotted line is the tidal height (scale on right axis).

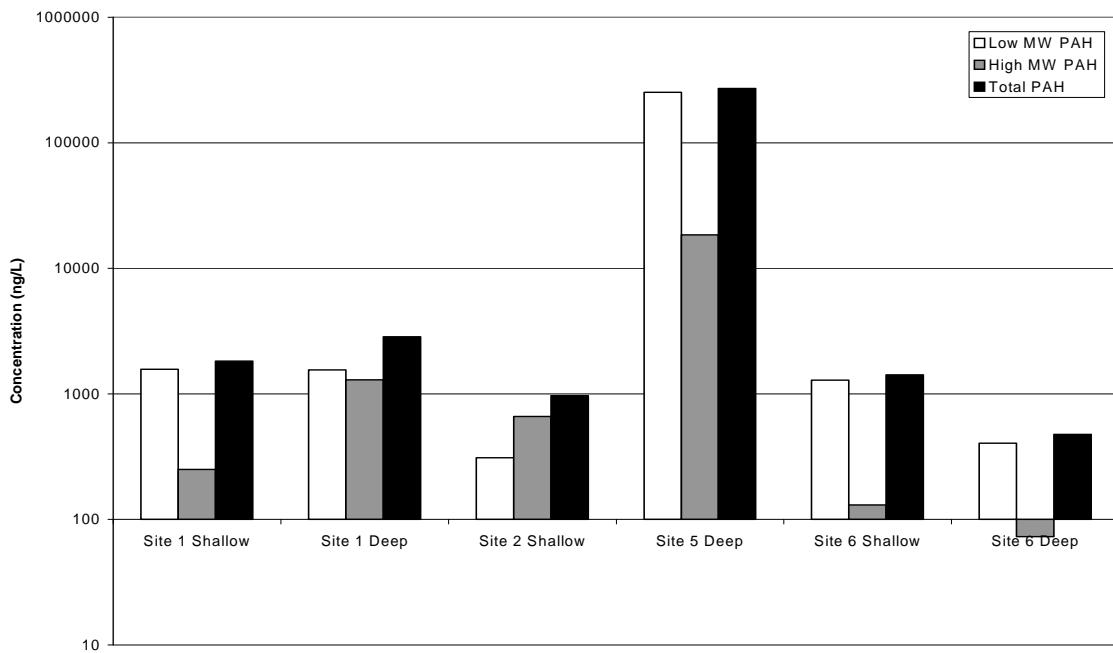


Figure 2-16. Total, low molecular weight (LMW), and high molecular weight (HMW) summations of PAH at four Anacostia River sites.

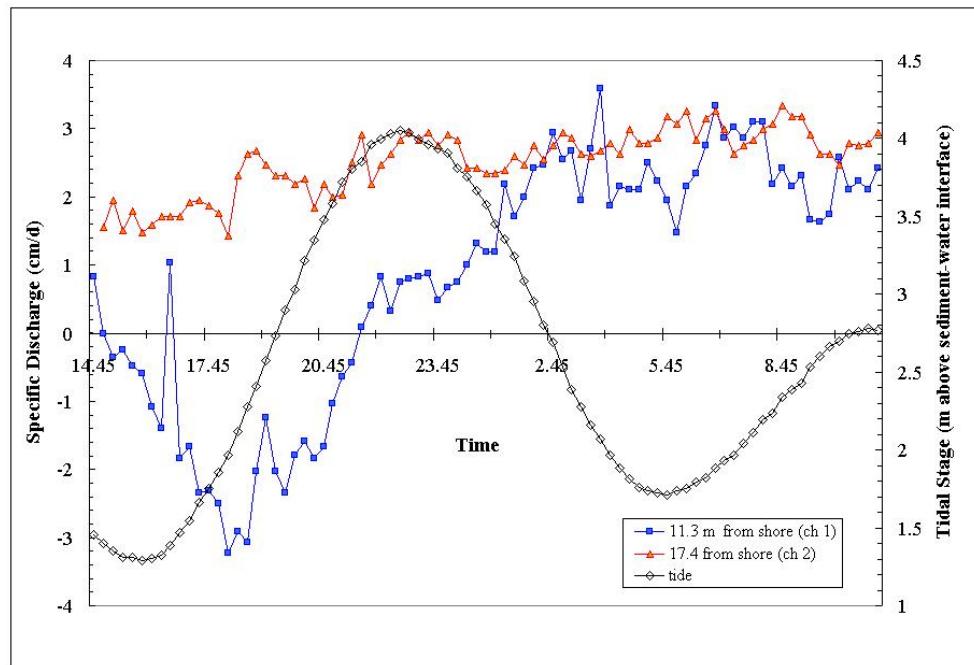


Figure 2-17. Specific discharge vs. tidal stage, transect 3 (12–13 July 2001). Data are in 15-min intervals.

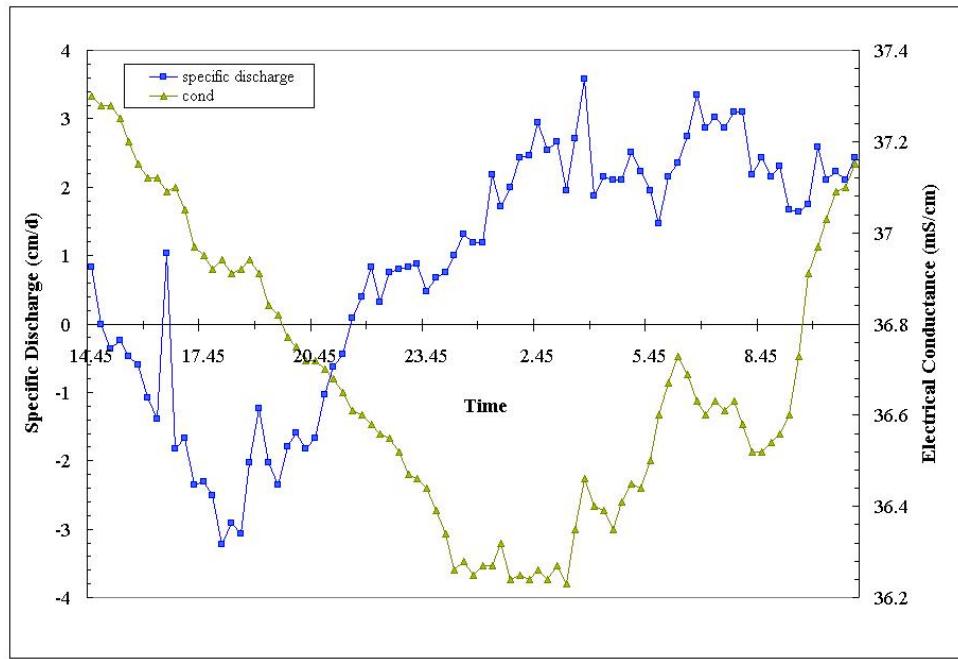


Figure 2-18. Specific discharge vs. electrical conductance within the collection funnel, transect 3, 11.3 m from shore (12–13 July 2001). Data are in 15-min intervals.

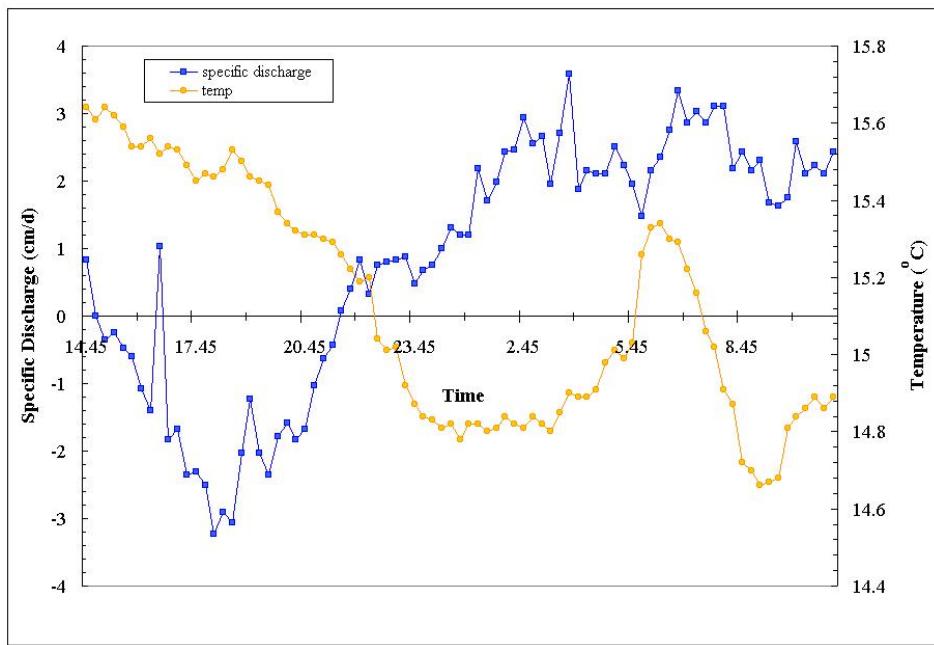


Figure 2-19. Specific discharge vs. temperature within the collection funnel, transect 3, 11.3 m from shore. Data are in 15-min intervals.

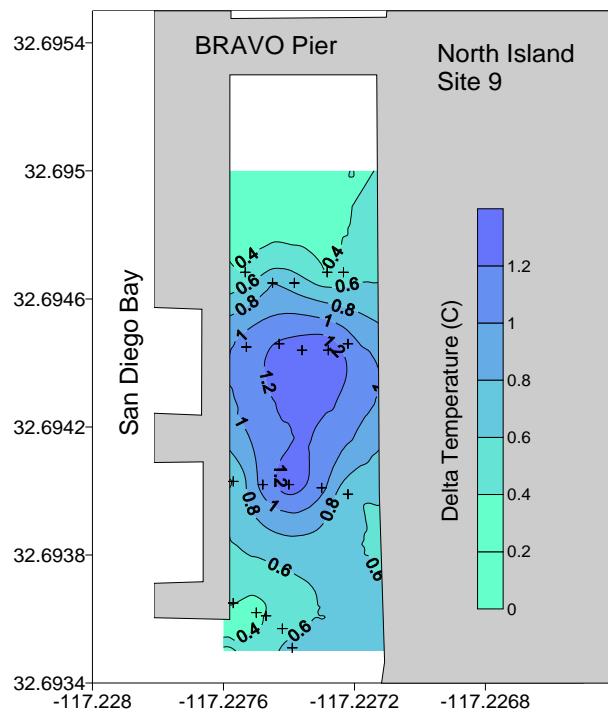


Figure 2-20. Temperature contrast contour map.

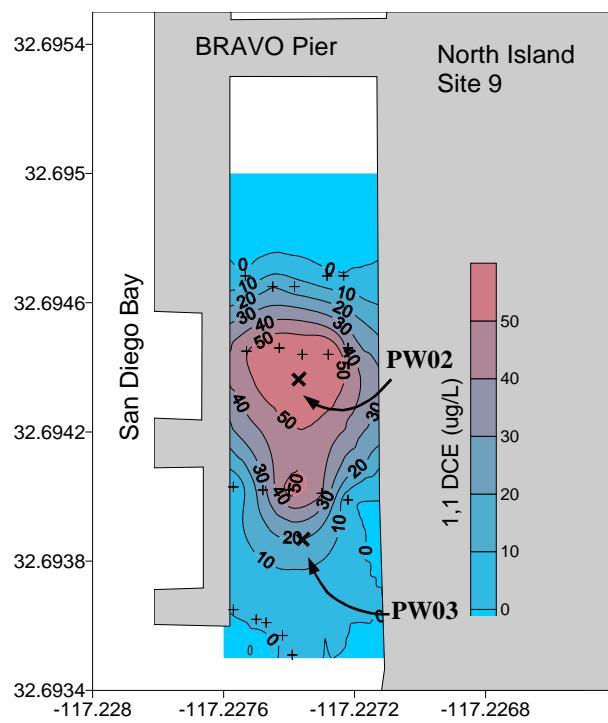


Figure 2-21. 1,1 DCE contour map from porewater samples collected with Trident probe.

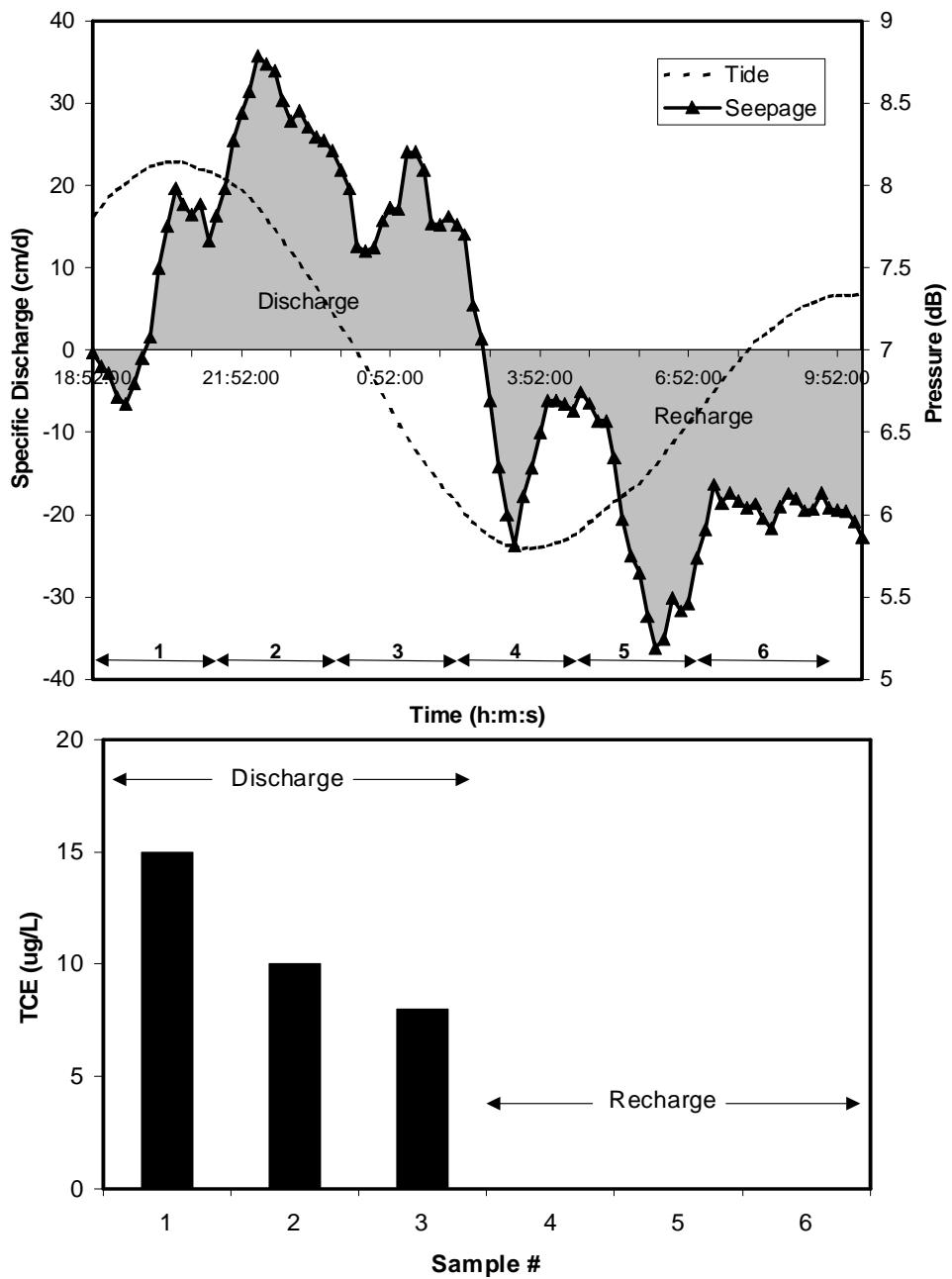


Figure 2-22. PW-02 UltraSeep TCE concentrations.

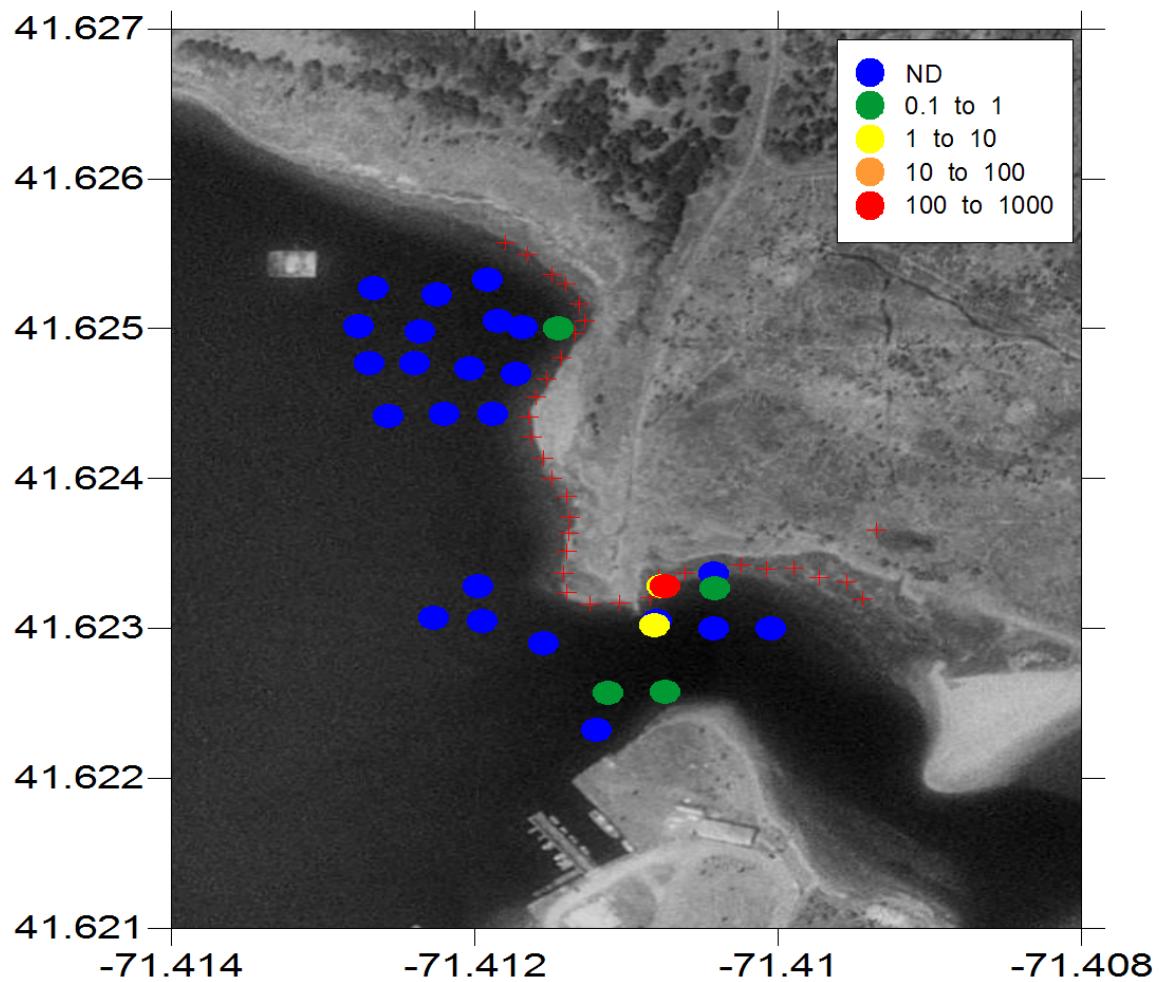


Figure 2-23. Trident probe subsurface TCE results for the Entrance Channel and Inner Harbor sampling areas at NCBC Davisville ($\mu\text{g}/\text{L}$).

2.3 FACTORS AFFECTING COST AND PERFORMANCE

The Trident probe and UltraSeep technologies represent an integrated system, and there are a number of mechanical and environmental factors that may influence performance. Anticipated performance factors addressed during the demonstration include factors that could affect the ability to perform the following tasks:

- Mobilize, operate, and demobilize the equipment: Demonstration includes successful testing and calibration of the commercial systems, and adequate access and support at the demonstration site
- Obtain field measurements within specified requirements of sensitivity: Demonstration includes verification of accuracy and precision for Trident probe and UltraSeep sensors, and documentation of method detection limits for Contaminant of Concern (CoC)-specific analytical methods
- Obtain field and equipment blanks that are free of contamination: Demonstration includes requirements for equipment blanks, trip blanks, and field duplicates
- Produce spatial maps of groundwater tracers at the sites of interest (Trident probe): Demonstration includes requirements for adequate study design incorporating sufficient spatial extent and station density to describe the area of interest
- Identify areas of potential groundwater/surface water interaction (Trident probe): Demonstration includes requirements for the presence of a detectable contrast between groundwater and surface water for temperature and/or conductivity. Also requires that CoCs are primarily related to groundwater rather than sediment or surface water sources
- Obtain continuous seepage flow records over required time periods (UltraSeep): Demonstration includes requirements for site conditions within the operating range of the system, including primarily water depth and discharge rate
- Obtain water samples during periods of positive seepage (UltraSeep): Demonstration includes requirements for proper mechanical function of the water sampling system and proper selection of deployment location in areas of potential discharge based on Trident probe data
- Quantify rates of seepage and chemical release at the measurement sites (UltraSeep): Demonstration includes requirements for proper mechanical function of the flow meter and water sampling system

Cost analysis for the demonstration phase will be based on an assessment of the costs that are documented during the demonstration, and estimates of expected costs for full-scale assessment at future sites. The primary cost components include the following:

- Equipment Costs, which include capital investment and maintenance and replacement of equipment
- Material Costs, which includes expendables such as cleaning solutions, sampling containers, sample storage and handling equipment, logbooks, etc.
- Mobilization Costs, which includes the costs associated with preparing and shipping the equipment to the site
- Site Operation Costs, which includes costs associated with the deployment, operation, and retrieval of the site equipment

- Demobilization Costs, which include costs associated with equipment breakdown and return shipment to the point of origin.
- Travel Costs, which includes airfare, per diem, car/truck rental, lodging, etc.
- Sample Analysis Costs, which include the analytical laboratory charges for both the Trident probe and UltraSeep samples for the target CoCs
- Data Analysis and Reporting Costs, which include the costs associated with analysis of the Trident probe and UltraSeep data (including sensor and water sample data and production of a study report)

2.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

2.4.1 Advantages of the Technology

Initial results from the new Trident probe and UltraSeep meter show that groundwater exchange at coastal sites can be an important process in the transport and fate of dissolved contaminants that emanate from terrestrial waste sites (see Section 2.2). Advantages of the Trident probe and UltraSeep technologies over traditional technologies include the ability to perform the following tasks:

- Identify the most likely areas of groundwater discharge
- Map these areas rapidly over large spatial areas
- Determine CoC concentrations at the point of exposure
- Collect a continuous seepage records to document the dynamics of the groundwater discharge process
- Collect water samples in proportion to the seepage rate, enabling the direct quantification of the chemical loading associated with the groundwater discharge

2.4.2 Limitations of the Technology

The Trident probe has undergone a series of laboratory and initial field tests, providing confidence that the system will perform well during the demonstration phase (Chadwick et al., 2002a). The potential limitations that we anticipate for the Trident probe based on experience from the initial testing phase are as follows:

- Potential inability to collect water in fine-grained sediments
- Potential absence of a temperature or conductivity contrast in the impinging groundwater
- Potential breakage of the probes on rocks or debris

The demonstration site at NSA Panama City was chosen with consideration of these potential limitations. The sediments are generally of a sandy nature, which should minimize any problems associated with clogging of the water sampler. The average salinity in St. Andrew Bay is about 31, while the salinity of groundwater measured in shoreline wells is near 0, indicating that conductivity contrast should be sufficient enough to identify areas of groundwater discharge. Finally, site inspection indicated that direct-push operations with the Trident probe would not be impeded by rock or debris.

As with the Trident probe, the success of the initial tests for the UltraSeep provide a high level of confidence for success during the ESTCP demonstration phase. The primary technical risks that we anticipate for the UltraSeep include the following:

1. Limited chemical detection due to dilution in the seepage funnel
2. Confounding effects of chemical diffusion into the funnel that could be interpreted as advection
3. Logistical problems associated with site access and leaving equipment deployed on site for a few days

The UltraSeep water sampler draws samples from the volume of water enclosed by the seepage funnel. The installed funnel has an average height of 2.67 cm and a volume of 5236 cm³. When the UltraSeep is installed, the water enclosed by the funnel is surface water. As discharge occurs, the funnel begins to fill with discharge water (groundwater). Thus, at least initially, the water sampling system may be sampling a mixture of surface water and discharge water. This dilution effect can be corrected for based on the measured flow rate and measured surface water concentration. However, the dilution may limit the detectability of the CoC.

For example, if the CoC has a detection limit (DL) of 1 µg/L, but the discharge water is diluted by a factor of 10 with surface water at 0 µg/L, then the detection of the UltraSeep will be limited to 10 µg/L. The extent to which this limit will impact the demonstration depends on site discharge rates and concentrations.

It is also possible for CoCs to release into the seepage funnel by diffusion rather than by advection associated with groundwater discharge, which could result in overestimating the release associated with groundwater discharge. At the NSA Panama City demonstration site, this possibility is not anticipated to be a significant issue because the primary CoCs are VOCs that are only associated with the groundwater. Thus, any release is likely to be associated with groundwater migration. Based on the site inspection and discussions with the site manager, any logistical or equipment security issues at the NSA Panama City site is not anticipated.

2.4.3 Alternative Technologies

To our knowledge, there is no comparable alternative technology to the Trident probe that integrates groundwater detection sensors with water sampling in offshore sediments. Direct-push technologies such as the GeoProbe® offer similar capabilities for terrestrial sites, but are not well suited to offshore application. Simple water samplers such as the “Henry” sampler offer an alternative means of collecting water that can then be analyzed using a portable water quality sensor, but they do not provide in situ sensing of temperature and salinity contrast.

The most commonly used technology for this application would be the installation of a network of temporary mini-wells (or piezometers). Piezometers can be installed semi-permanently or temporarily and are relatively economical from a capital investment perspective. Water levels are measured with a pressure manometer and samples are recovered using a peristaltic pump. The main advantage of piezometers over the Trident probe is the ability to return to the site and easily resample from exactly the same location.

While piezometers are relatively easy to install in shallow, shoreline, or wetland environments, they can be difficult or infeasible to install and access in deeper water. Another major disadvantage of the piezometer system is that it must be left in place, which may not be logistically acceptable at many sites. In addition, although the piezometer arrays are relatively

inexpensive, a significant amount of maintenance is required when used in a high-energy sampling site.

Piezometers and the “Lee” meter are most commonly used technologies for assessing seepage. As described above, advantages of piezometers include relatively low costs and the ability to resample the same location over time. However, piezometers do not provide a direct measurement of seepage, so the flow rate must be inferred from the measured water level difference between the piezometer and the surface water. This requires additional knowledge of the sediment hydraulic conductivity.

Advantages of the Lee meter over the UltraSeep are the simplicity and low cost of the system. Disadvantages include potential measurement errors associated with the “closed-system” nature of the meter, inability to resolve tidal/temporal variation in seepage except by manually switching out the sampling bags, and the absence of any confirmatory sensing system such as temperature or conductivity.

The most comparable technology to the UltraSeep is the thermal perturbation detection seepage meter developed by Taniguchi and Fukuo (1993). While the meter provides continuous flow measurement, the flow sensor is only responsive in one direction, and the meter provides no automated method of collecting water samples for chemical analysis. In addition, the system is not commonly used or commercially available.

3. DEMONSTRATION DESIGN

3.1 PERFORMANCE OBJECTIVES

Performance objectives for the Trident probe and UltraSeep technologies provide a basis for evaluating the systems success during the demonstration. As described in Section 2, the performance of the Trident probe and UltraSeep technologies can be categorized as follows:

3.1.1 Trident Probe

- Mobilize, operate, and demobilize the equipment
- Obtain field measurements within specified measurement quality objectives
- Obtain field and equipment blanks that are contaminant-free
- Collect valid water samples of sufficient volume to characterize CoC distributions
- Produce spatial maps of groundwater tracers at the sites of interest
- Identify the presence or absence and areas of potential groundwater CoC discharge to surface water

3.1.2 UltraSeep

- Mobilize, operate, and demobilize the equipment
- Obtain field measurements within specified measurement quality objectives
- Obtain field and equipment blanks that are contaminant-free
- Obtain valid, continuous seepage flow records over required time periods
- Obtain valid discharge water samples of sufficient volume to characterize CoC concentrations during periods of positive seepage

Baseline measurements for comparison with the Trident probe water sample results will be developed using piezometers installed at a subset of the Trident probe stations. Water samples will be collected synoptically from the Trident probe and the adjacent piezometer. VOC concentrations and water quality characteristics will be compared.

Baseline measurements for comparison with the UltraSeep flow and water sample results will be developed using piezometers installed adjacent to each of the three UltraSeep stations. Calculated flow rates based on water level and hydraulic conductivity measurements in the piezometers will be compared to the direct flow measurements from the UltraSeep. Shallow piezometer water samples will be compared to dilution-corrected discharge concentrations measured in the UltraSeep.

3.2 SELECTING TEST SITES

A number of sites were evaluated as candidate demonstration sites. For the Navy, these include Naval Station San Diego, Pearl Harbor Naval Shipyard, NSA Panama City, NTC Orlando, Point Magu, and Hunter's Point. Initial discussions with RPMs and review of site documents at these sites and elements from a previous survey of Navy sites are included in Appendix 2. Ira May at the U.S. Army Environmental Center was contacted regarding potential Army sites, including Aberdeen Proving Ground and many inland freshwater sites. This contact led to follow-up discussions with Dr. Michelle Lorah and a site visit to the Aberdeen Proving Ground.

There are many specific requirements and preferable characteristics for the demonstration sites. In general, the site should be adjacent to a surface water body and have an identified contaminated groundwater plume. Surface water regulatory standards should be a potential driver for the site assessment. Enough spatial delineation should be available from the terrestrial assessment to indicate that the groundwater plume is approaching the surface water body. The CoCs at the site should be identified, and the range of concentrations in the terrestrial wells should be known.

Preferably, good data regarding the geology of the site and potential migration pathways to surface water should be known. Groundwater modeling results may also help determine if surface water release is likely, and where areas of release may be most likely to occur.

In addition to the above, preferable site characteristics include the following:

- Easy accessibility to the site
- Minimal interference with ongoing operations at the site
- Groundwater discharge rates >1 cm/day
- Significant temperature and/or salinity contrast between groundwater and surface water (>1 °C or >1 ppt).
- Groundwater CoCs distinctive from background surface water or interstitial water concentrations
- Site manager and regulatory buy-in
- Appropriate timing relative to status of site assessment

Final selection for the first demonstration site was completed during the first quarter of Calendar Year (CY) 2004 in consultation with NFESC, Cal/EPA, and the site managers. On the basis of the factors listed above, the NSA Panama City site was selected. In general, the site is an ideal candidate for the demonstration of these technologies. The demonstration will focus on evaluation of a VOC plume associated with AOC 1 at NSA Panama City.

The site is adjacent to St. Andrews Bay, and the plume appears to be migrating toward the bay. Surface water regulatory standards (Florida Surface Water Cleanup Target Level) are the primary regulatory driver at the site. The plume on the terrestrial side has been well delineated using monitoring wells and direct-push technology (DPT). The primary CoC has been identified as 1,1-DCE (Jordon, 1987; Southern Division Naval Facilities Engineering Command, 2002; Southern Division Naval Facilities Engineering Command, 2004).

Access to the NSA Panama City site via a shoreline road and beach adjacent to the off-shore study area. Based on discussions during the site visit, no interference with ongoing activities at the site was anticipated. Although groundwater discharge rates were unknown, there was a clearly defined hydraulic gradient toward St. Andrew Bay from AOC 1. There was also a strong salinity gradient, with most of the monitoring wells indicating freshwater, and high salinity water in St. Andrew Bay.

The 1,1-DCE was distinctive from any background contamination in the bay, thus reducing potential confounding influences of natural/background sources. Buy-in from the site and the regulators was strong, and the technologies were incorporated into the planned Corrective Measures Study for the site (Southern Division Naval Facilities Engineering Command, 2004). The timing of the demonstration fit well within the site schedule. A detailed description of the site history and characteristics is provided below.

Final selection for the second demonstration site was completed in December 2004. The site selected for the second demonstration was NTC Orlando, Operable Unit 4 (OU 4). The site was selected based on its compliance with the criteria discussed above, and its contrast to the NSA Panama City site used for the first demonstration.

Access to the Orlando site was good. Although groundwater discharge rates were unknown, there was a clearly defined hydraulic gradient toward Lake Druid from OU 4. There was little or no salinity or conductivity gradient between groundwater wells adjacent to Lake Druid and surface waters in the lake that could be determined from sparse simultaneous groundwater and lake data, but temperatures appeared to contrast enough to detect possible groundwater seepages using the Trident probe.

The NTC Orlando site was significantly different from the NSA Panama City site in that it was a freshwater lake environment with no tidal influence, and had significantly higher CoC levels. The primary target CoC (PCE) was also different than the primary target for NSA Panama City (1,1-DCE). Thus the Orlando site helped to test the range of applicability of the technologies. A detailed description of the site history and characteristics is provided below.

3.3 TEST SITE HISTORY/CHARACTERISTICS

3.3.1 NSA Panama City

Investigation and remediation of contaminated media at Naval Support Activity (formerly Coastal Systems Station) Panama City is being performed under the Corrective Action Program of RCRA and the Hazardous and Solid Waste Amendments (HSWA) (Jordon, 1987; Southern Division Naval Facilities Engineering Command, 2002; Southern Division Naval Facilities Engineering Command, 2004). Under this program, the following stages have been implemented:

- RCRA Facility Assessment (RFA) 1987
- RCRA Facility Investigation (RFI) 1996
- Corrective Measures Study (CMS) 1997
- RFI Addendum 2003

Sites maps of AOC 1 at NSA Panama City are shown in Figures 3-1 through 3-7.

Based on recommendations in the original RFI, the original CMS focused on four sites, Solid Waste Management Units (SWMUs) 3, 9, and 10, and AOC 1 (Figures 3-1 and 3-2). Between 1997 and 2002, several corrective actions were implemented at the sites to address contaminated soils and the presence of free-product. Of the four sites, AOC 1 was the primary site identified where contaminated groundwater could be discharging to the surface water of adjacent St. Andrew Bay (Southern Division Naval Facilities Engineering Command, 2002; Southern Division Naval Facilities Engineering Command, 2004).

For 1,1-DCE at AOC 1, a DPT investigation in 2001 and monitoring well sampling in 2002 and 2003 showed exceedences near St. Andrews Bay of the Florida Marine SWCTL of 3.2 µg/L (Figure 3-3 through 3-5). The DPT investigation indicated that 1,1-DCE is completely depleted in the source zone, but has migrated laterally to the edge of St. Andrews Bay at concentrations slightly above the SWCTLs (Figure 3-6).

However, the 1,1-DCE exceedences occur at depths of 10 to 30 ft below the water table such that further migration (vertically upward) is required before contamination would discharge into the surface water of the bay. Since there are no wells or DPT locations in the bay, it was unknown where the discharge to surface water would occur. Theoretically,

it was possible that the contaminants would attenuate (through biodegradation, dilution, and dispersion) prior to reaching surface water, especially since the source had been eliminated, and the measured concentrations were close to the SWCTL. The Trident probe and UltraSeep results were used to evaluate this hypothesis.

Because the 2002 and 2003 sampling suggested the potential for groundwater containing 1,1-DCE to discharge to surface water, the following Corrective Action Objective (CAO) for AOC 1 was developed:

Additional CAO 3: Address potential surface water discharge of AOC 1 groundwater containing 1,1-DCE concentrations greater than the Florida SWCTL. Media Protection Standards for AOC 1 groundwater discharging to St. Andrew Bay, the Media Protection Standard (MPS) would be the state of SWCTL, Southern Division Naval Facilities Engineering Command, 2004).

3.3.2 NTC Orlando

Naval Training Center (NTC) Orlando was identified as an installation for closure by the Base Closure and Realignment Commission. Contaminated media on this installation have been investigated under the Installation Restoration (RI) program and the BRAC program. Southern Division Naval Facilities Engineering Command; U.S. EPA, and FDEP coordinated cleanup activities through the BRAC cleanup team called the Orlando Partnering Team (OPT).

The OU 4 Study Areas (SA) 12, 13, and 14 (Figure 3-8 and 3-9) were first investigated during a BRAC Environmental Baseline Survey (EBS) in 1994. Site screening investigations began in January 1995. This investigation showed PCE and trichloroethene (TCE) were measured in soil north of Building 1100, a former laundry. Building 1100, located in SA 13, was constructed in 1943 and used as a laundry and dry cleaning facility until 1994. The PCE source area is generally beneath the northern portion of former Building 1100, where the dry-cleaning operations were located.

The PCE was most likely released by leaks in the wastewater collection and conveyance system (e.g., drainlines and floor drains) inside the building and operational spills in and around Building 1100. Sub-surface investigations at OU 4 identified groundwater contamination associated with the former laundry and dry-cleaning operations at Building 1100. Groundwater samples between Building 1100 and Lake Druid contained PCE, *cis*-1,2-dichloroethene (*cis*-DCE), and TCE. Groundwater well sampling locations are shown in Figure 3-10.

Water samples collected along the lakeshore contained chlorinated solvents, including PCE, TCE, *cis*-DCE, 1,1-dichloroethane, and VC. Lake sediment samples also contained PCE and TCE. The highest surface water and sediment VOC concentrations were detected where a small ditch formed along the eastern shoreline. A focused field investigation (FFI) was conducted in May 1996 to delineate the VOC contamination in groundwater along the lake shore.

The CoCs at OU 4 are PCE and its degradation products (TCE, *cis*-DCE, and VC) in groundwater and in the surface water and sediments of Lake Druid. Antimony was also detected in groundwater at SA 14. Initial plumes of VOCs and antimony are shown in Figure 3-11. VOC concentrations are shown in Figure 3-12. Building 1100 was demolished during January–March 2004.

A dual recirculation well remediation system was installed in the spring of 1998 as an interim remedial action (IRA) to prevent migration of contaminated groundwater to Lake Druid. The effectiveness of the dual recirculation well system was evaluated in May 2000 as a result of ongoing operational difficulties. The evaluation determined that the dual recirculation well system could not meet the IRA objective of plume containment. As a result, the existing facilities were dismantled and the system was modified to operate as a groundwater extraction and treatment system (pump and treat system) with ex situ air stripping prior to discharge to the City of Orlando sanitary sewer system. The modified system began operation in January 2001 and has operated continuously since startup, except for occasional periods of maintenance and power outages.

The general groundwater flow patterns are very similar in the shallow and deep zones of the surficial aquifer (Figure 3-7). The natural gradient is from east to west towards Lake Druid. The groundwater extraction system captures contaminated groundwater migrating towards Lake Druid. When operating, groundwater flow decreases to the lake. A very slight downward vertical gradient is evident across eastern and central portions of the site. A slight upward vertical gradient is evident near Lake Druid (Figure 3-8).

A review of existing temperature and conductivity data from groundwater wells (Southern Division Naval Facilities Engineering Command, 2004) near Lake Druid and corresponding lake conditions (City of Orlando monitoring data, personal communication) showed a temperature difference, but not much conductivity difference between ground and surface waters that the Trident probe could detect (Table 3-1). These data were taken in the early spring of 2004. Greater temperature differences were expected in the summer months when lake temperatures rise with atmospheric changes more rapidly than groundwater would be expected to increase. Bottom lake temperatures ranged from about 16.5° C during winter months to almost 30° C in the summer. Using temperature alone demonstrated the Trident probe's ability to detect a seep area in a freshwater environment.

3.3.3 Current Operations

3.3.3.1 NSA Panama City

To address Additional CAO 3 for AOC 1 groundwater, technologies were identified from the Federal Remediation Technologies Roundtable treatment technologies screening matrix (http://www.frtr.gov/matrix2/top_page.html), published literature, and professional experience. Technology screening was performed to eliminate technologies that may not perform satisfactorily based on specific site conditions (Southern Division Naval Facilities Engineering Command, 2004).

A number of technologies were inapplicable for the site, including (1) physical barrier, (2) permeable reactive barrier, (3) pump and treat, (4) thermal treatment, (5) enhanced reductive dechlorination, and (6) air sparging/soil vapor extraction. Two technologies were considered applicable for the site, including biosparging and MNA.

Under the MNA option, it is envisioned that contaminant concentrations will be reduced to acceptable levels by natural processes such as biodegradation, chemical reactions, volatilization, dilution, and adsorption. Monitoring would occur to measure contaminant concentrations, determine degradation processes, estimate degradation rates, and watch for plume expansion or contraction (Southern Division Naval Facilities Engineering Command, 2004).

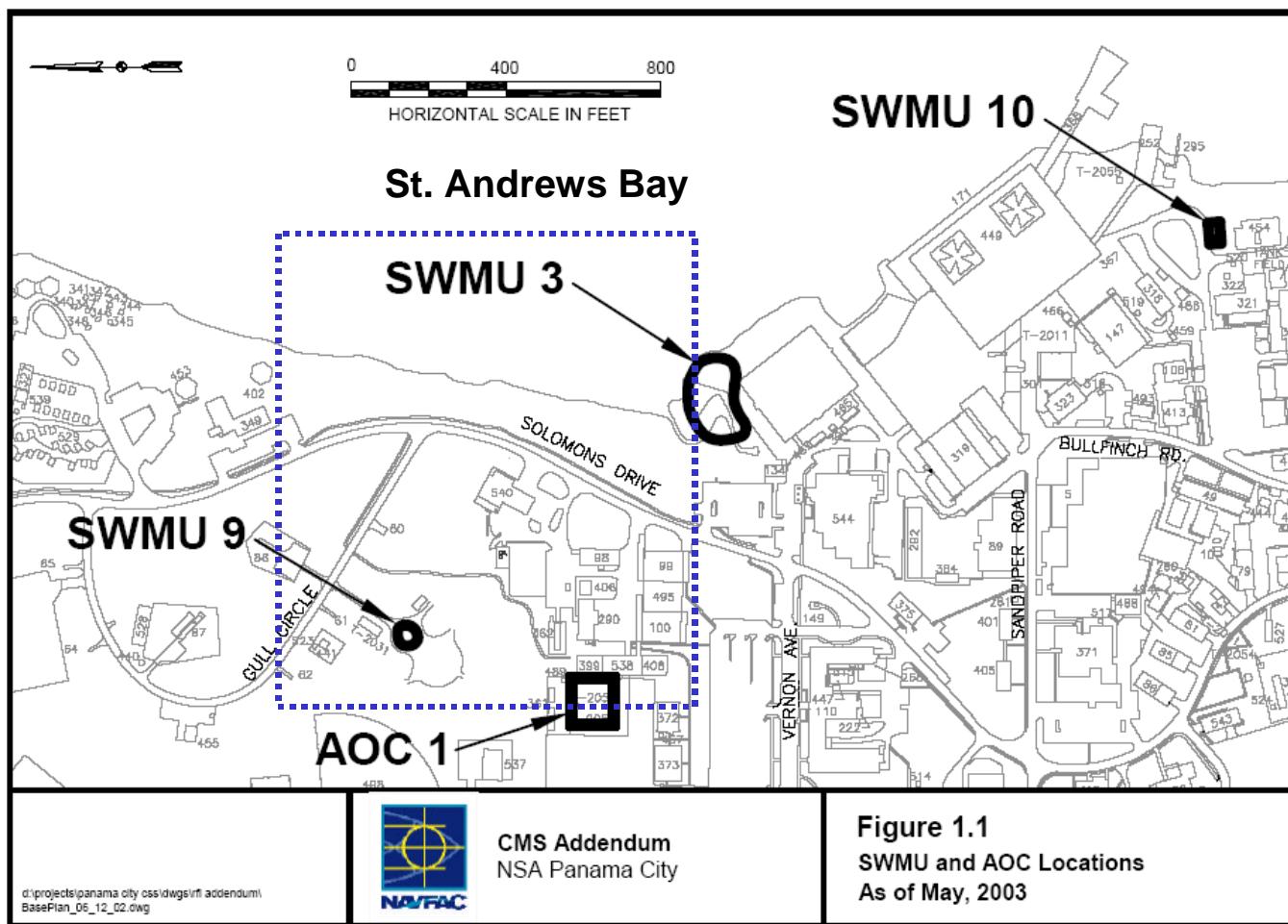


Figure 3-1. Map showing location of AOC 1 at NSA Panama City relative to St. Andrews Bay. Blue dotted line indicates approximate location of aerial photo in (adapted from Southern Division Naval Facilities Engineering Command, 2004).



Figure 3-2. Aerial photo extending from AOC 1 near bottom right to the offshore study area in St. Andrews Bay at top.

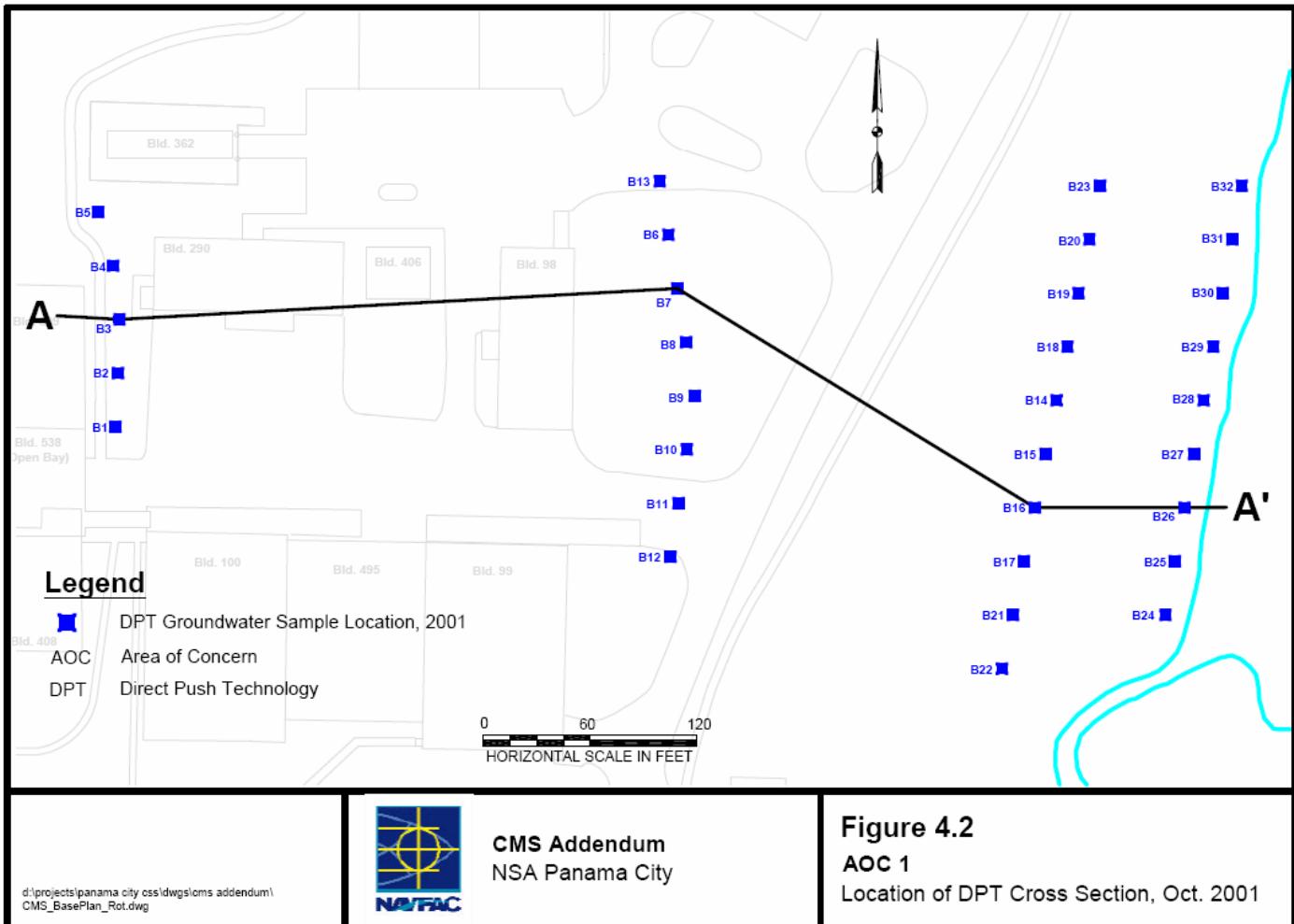


Figure 3-3. Map showing locations of DPT sample locations and location of cross section shown in Figure 3-4.
(from Southern Division Naval Facilities Engineering Command, 2004).

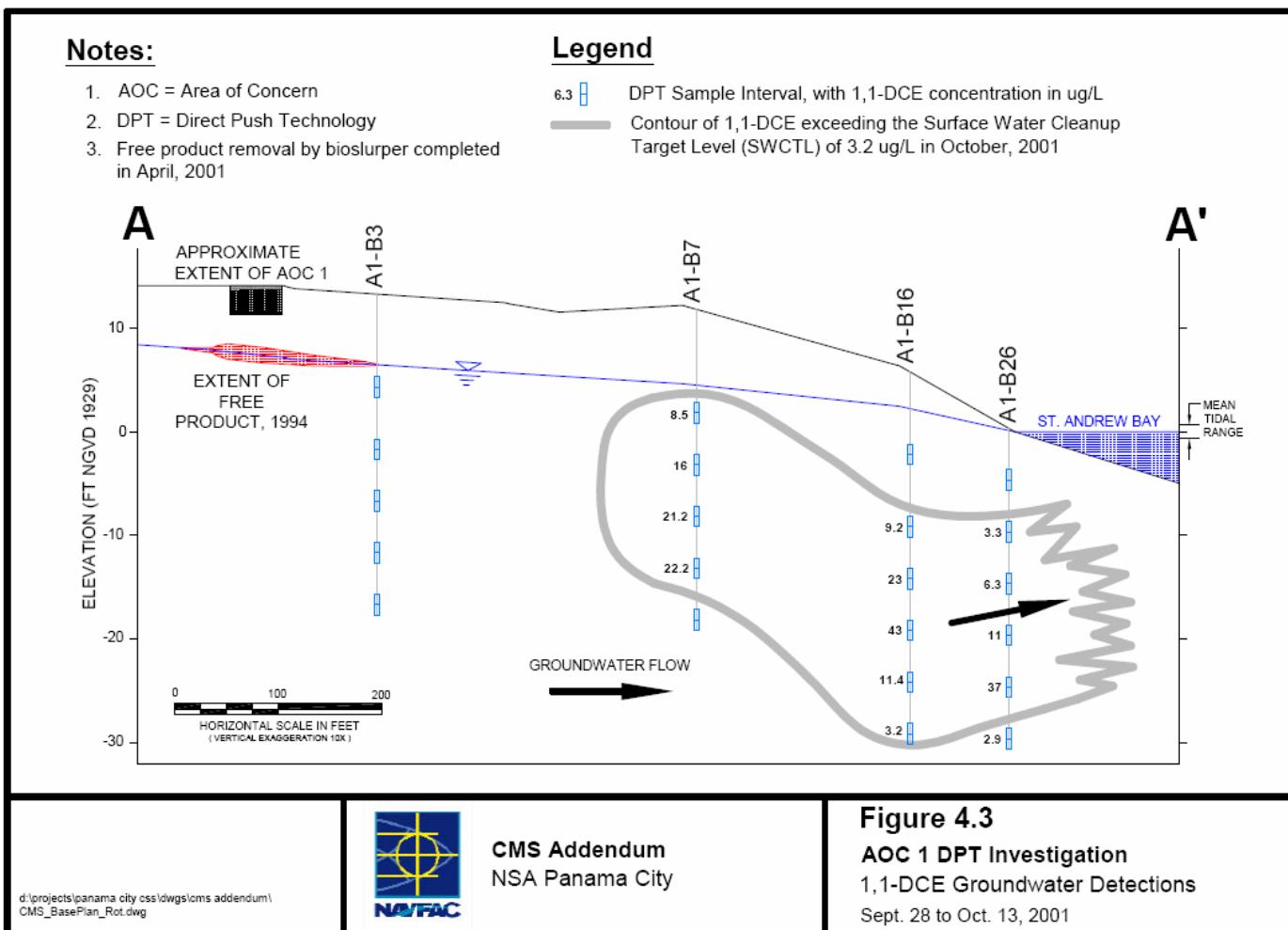


Figure 3-4. Vertical cross section showing approximate location of the 1,1-DCE plume relative to AOC 1 and St. Andrews Bay.
(from Southern Division Naval Facilities Engineering Command, 2004)

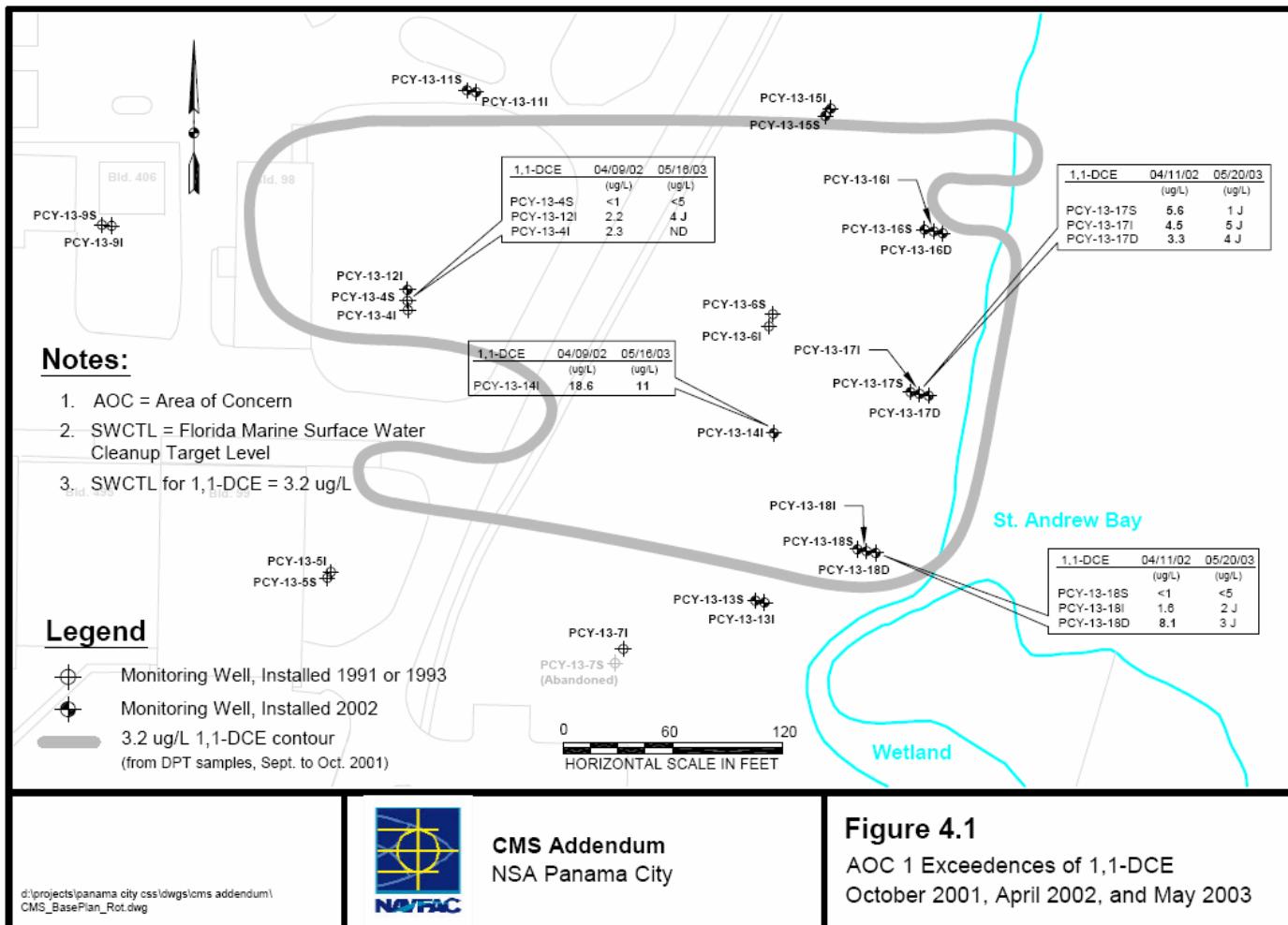


Figure 3-5. Plan view showing locations of permanent well borings and locations of 1,1-DCE exceedences relative to AOC 1 and St. Andrews Bay (from Southern Division Naval Facilities Engineering Command, 2004).

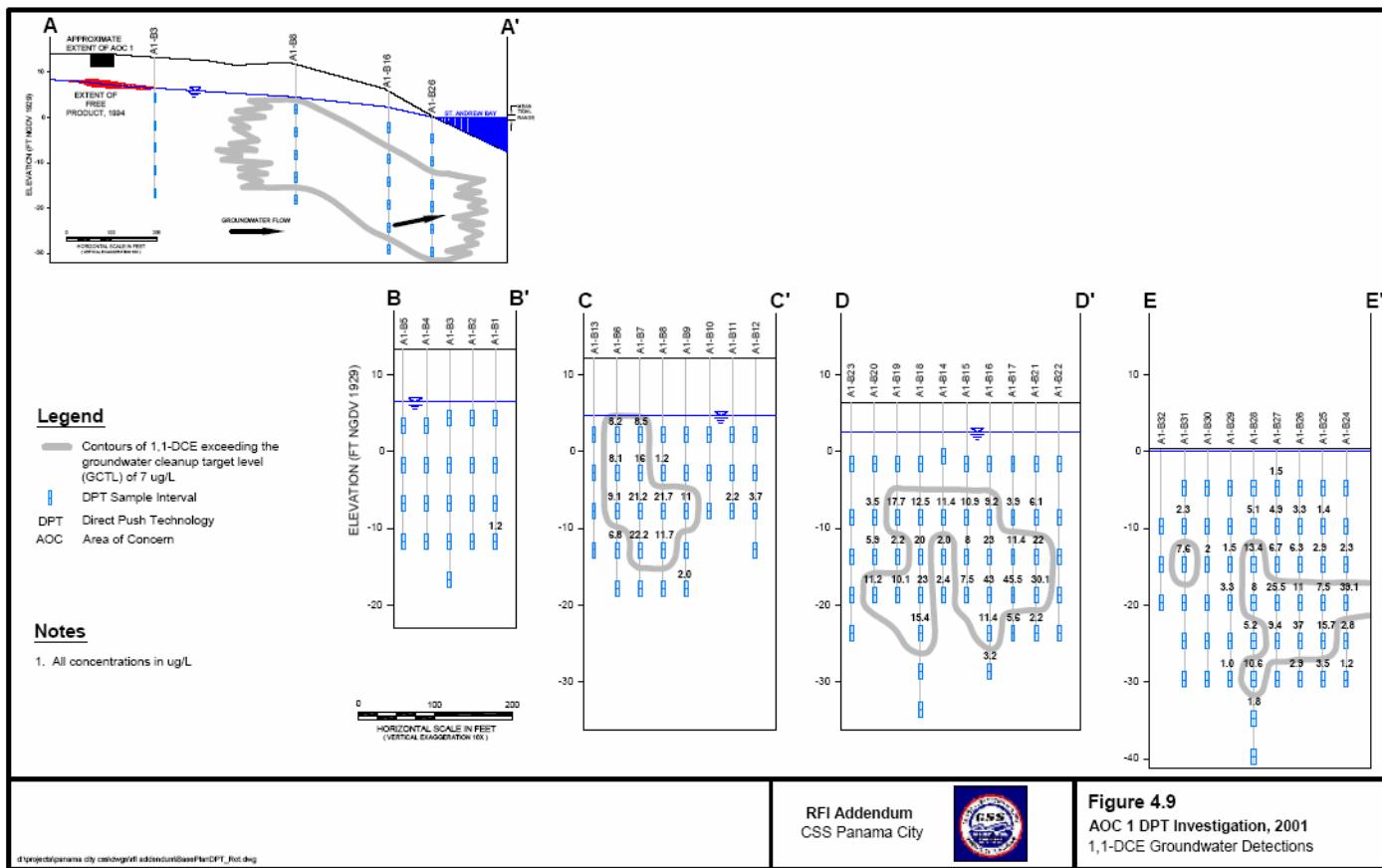


Figure 3-6.Cross-sectional distributions of 1,1-DCE showing lateral and vertical extent of the groundwater plume based on DPT samples.
(from Southern Division Naval Facilities Engineering Command, 2002)

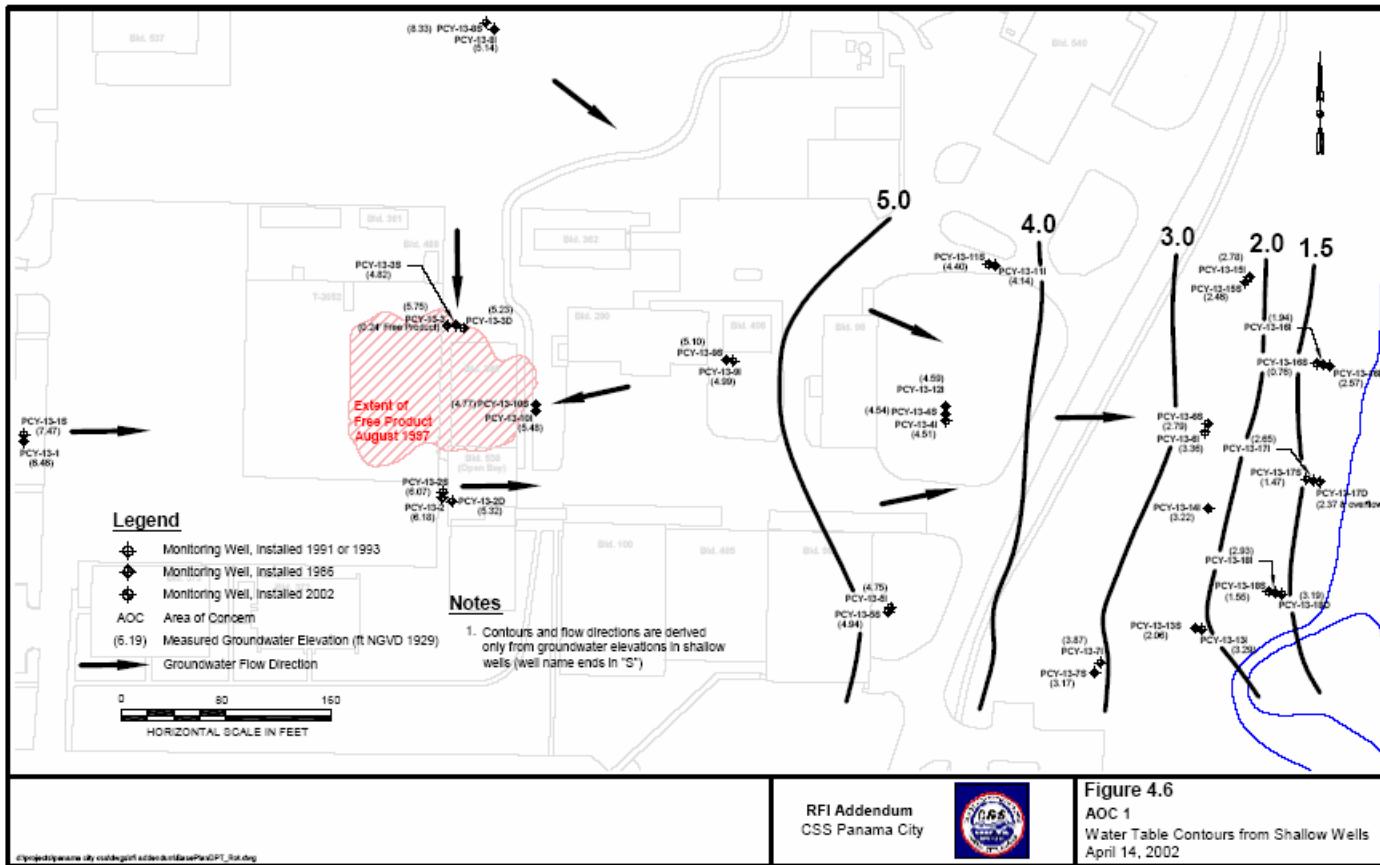


Figure 3-7. Map showing hydraulic gradients and flow patterns in the region between AOC 1 and St. Andrews Bay.
(from Southern Division Naval Facilities Engineering Command, 2002)

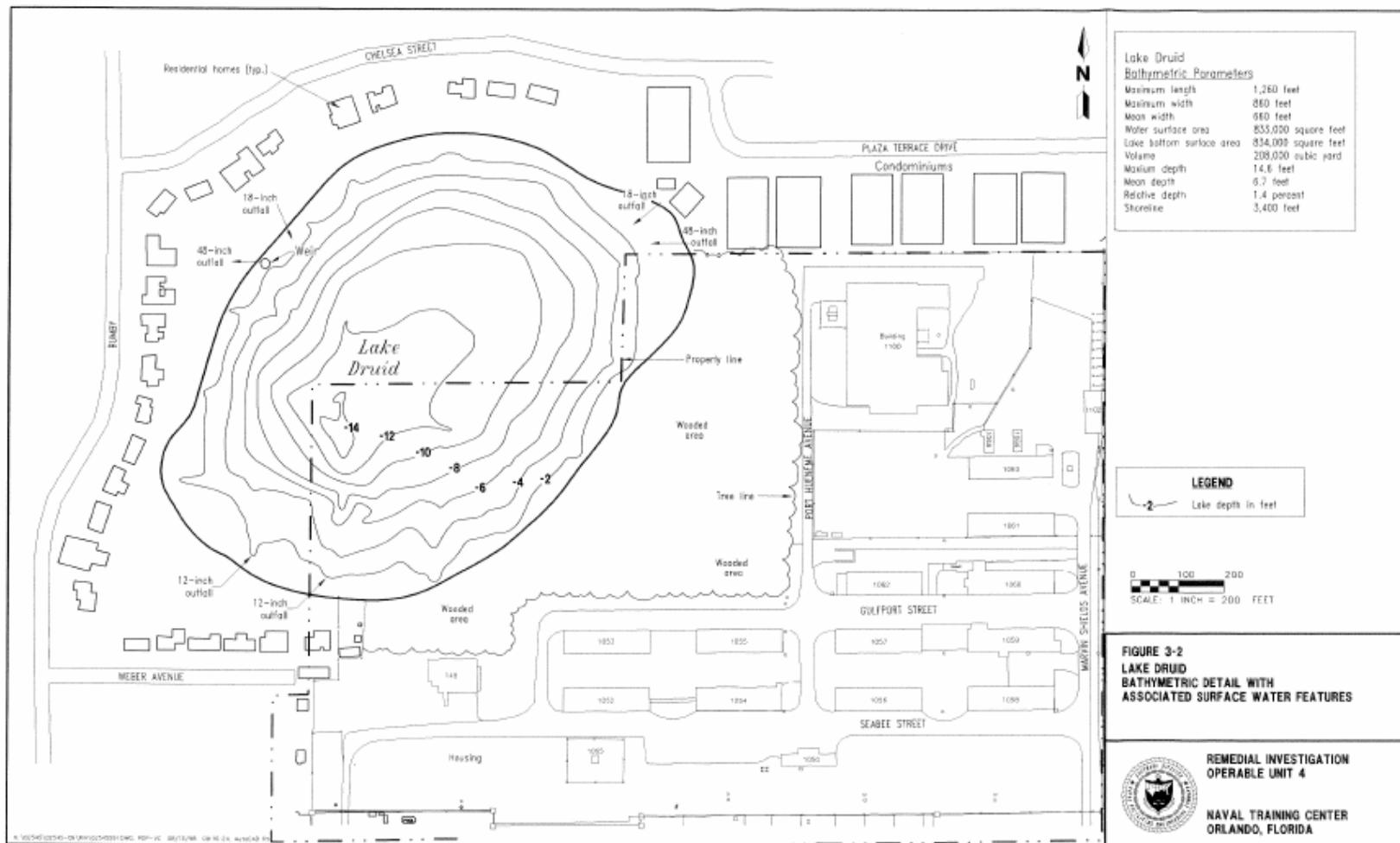


Figure 3-8. Map showing location of OU 4 and Lake Druid at NTC Orlando (adapted from Southern Division Naval Facilities Engineering Command, 2001).

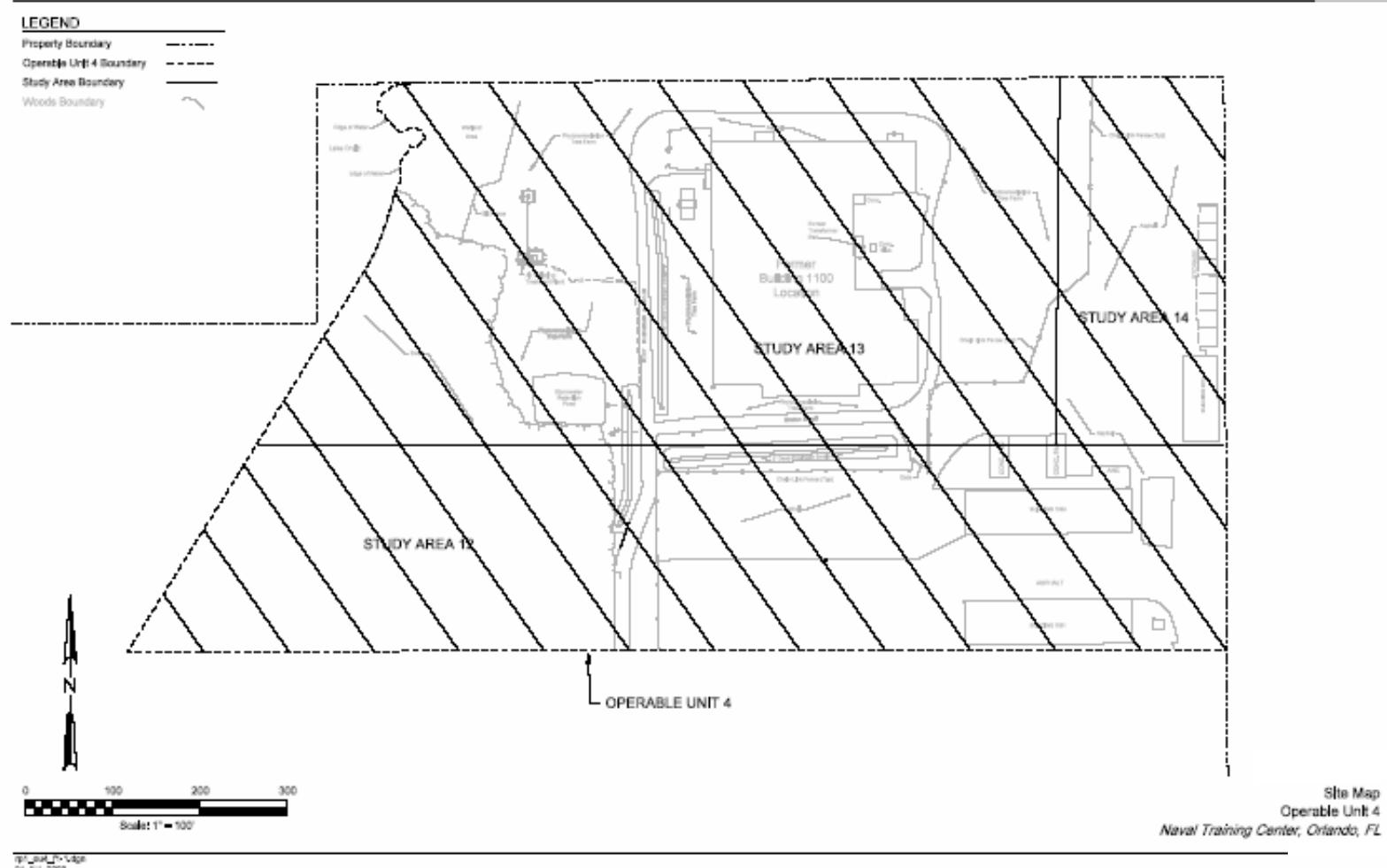


Figure 3-9. Site map of Operable Unit 4, Study Areas 12, 13, and 14.
(adapted from Southern Division Naval Facilities Engineering Command, 2004a).

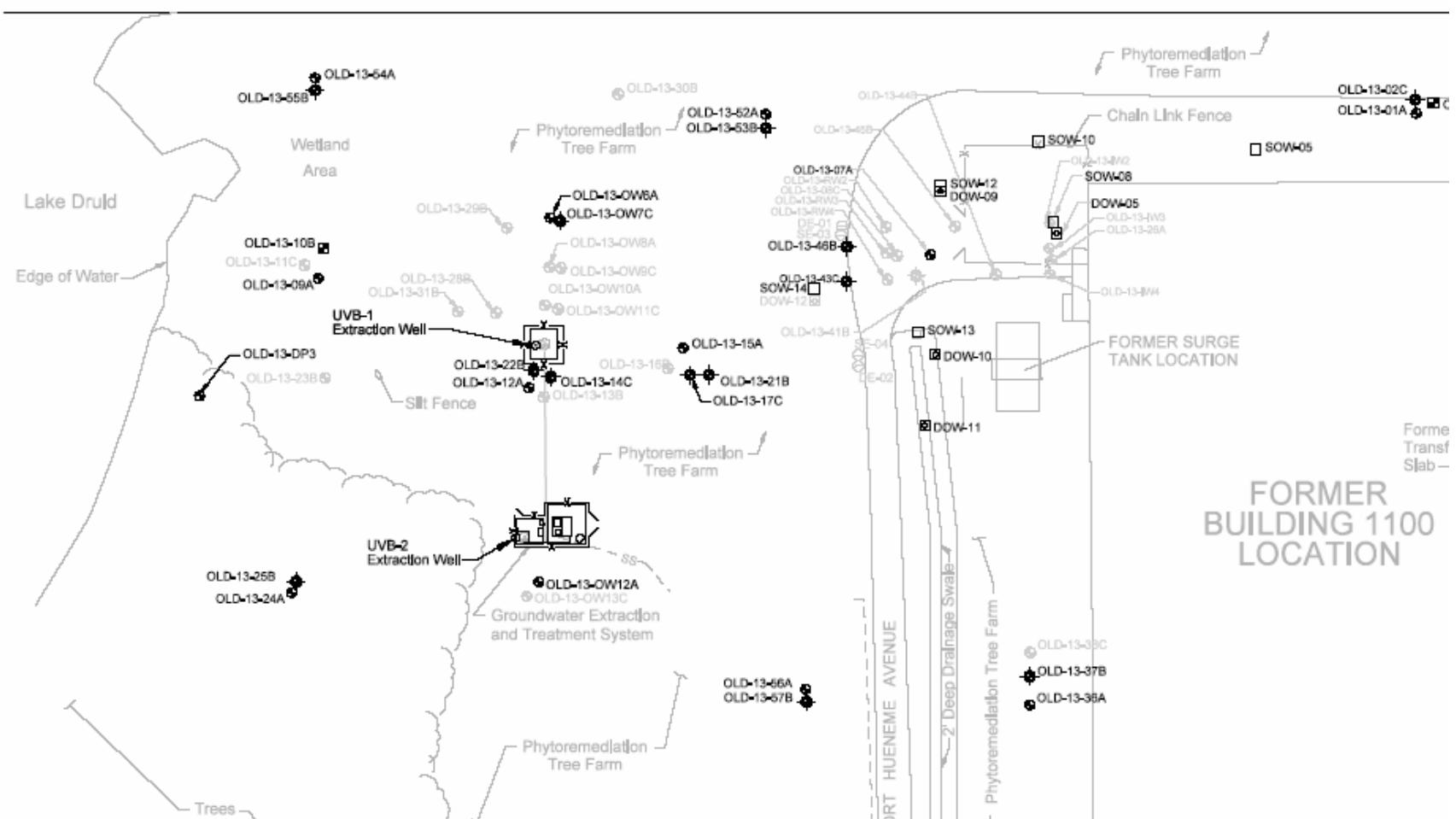


Figure 3-10. Map showing sampling well location.
(adapted from Southern Division Naval Facilities Engineering Command, 2004a)

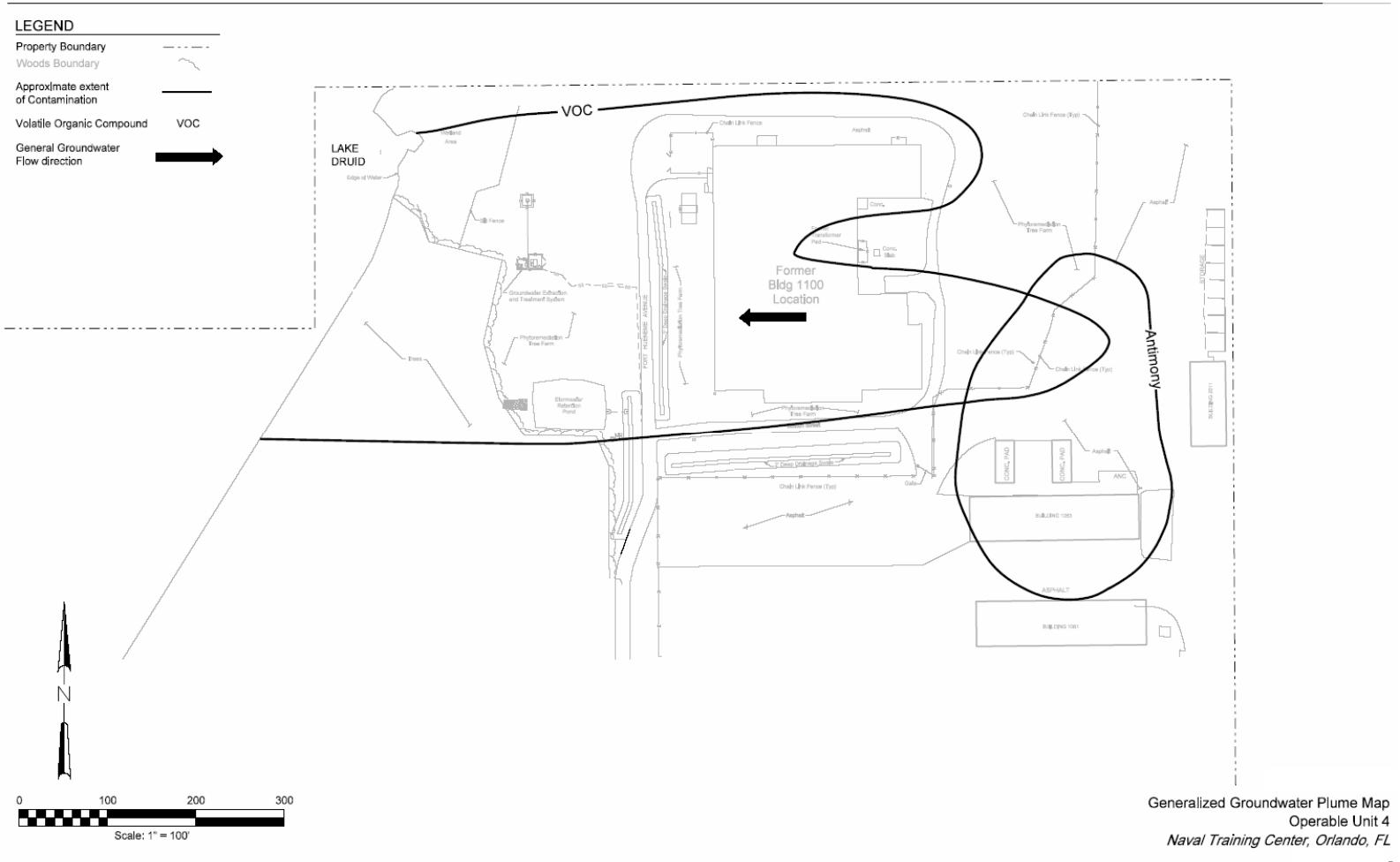


Figure 3-11. Generalized groundwater plume map for VOCs and antimony. (from Southern Division Naval Facilities Engineering Command, 2004a)

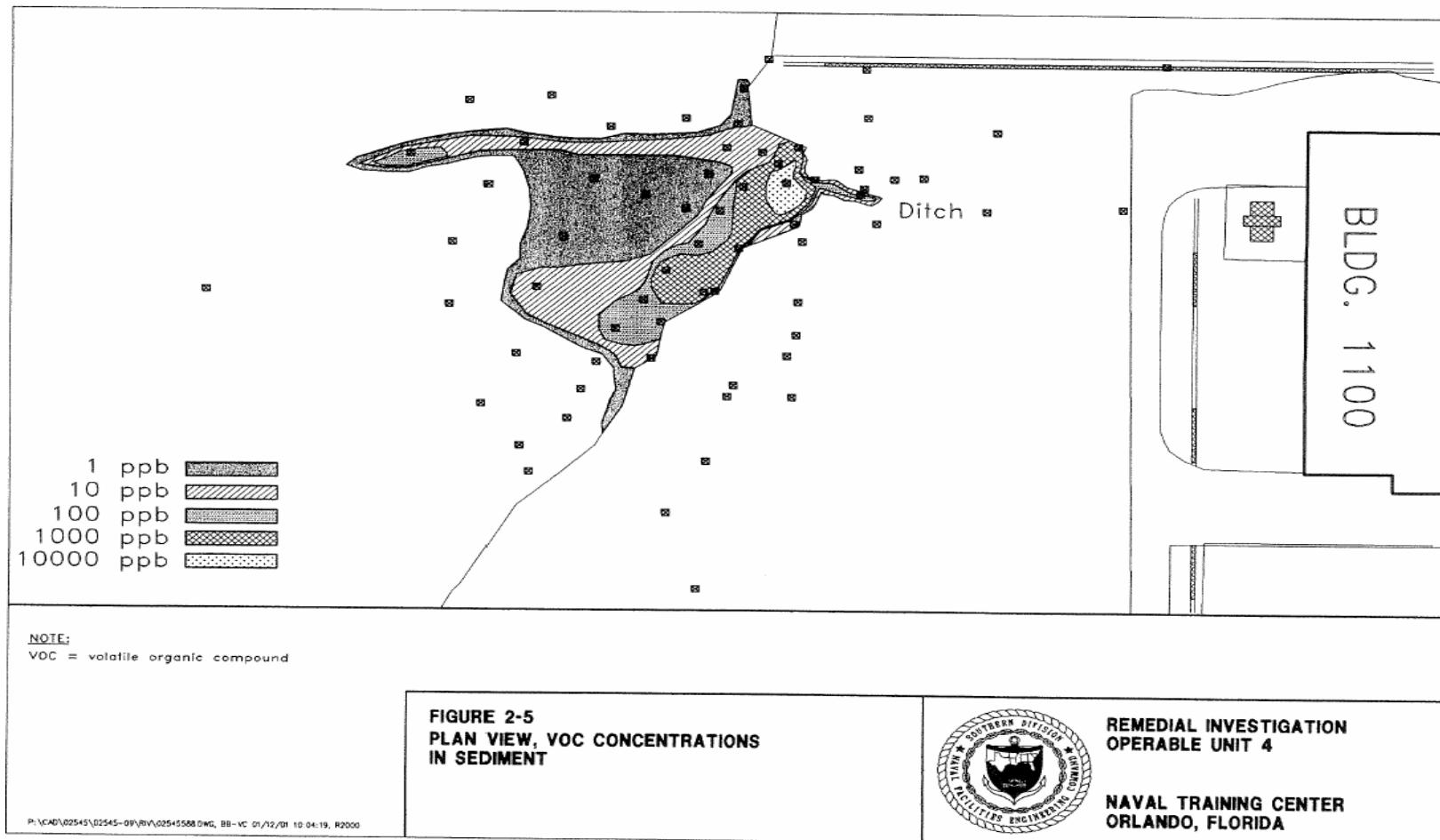


Figure 3-12. VOC concentrations in sediment.
(from Southern Division Naval Facilities Engineering Command, 2001)

Table 3-1. Temperature and conductivity differences the Trident probe may see between groundwater and lake water.
 (Data taken from Southern Division Naval Facilities Engineering Command (2004) and City of Orlando Lake Druid water quality).

	Well No.	Well depth (ft.)	Depth to well water from ground surface (ft.)	Sampling Date	Avg. GW Temp. (C)	Avg. Summer Lake Temp. (C)	Avg. Temp. Contrast (C)	Avg. Cond. (uS/cm)	Avg. Summer Lake Cond. (uS/cm)	Avg. Cond. Contrast (uS/cm)
Wells on lake shore	old-13-09A	13.91	3.83	2/26/2004	21.53	29.64	8.11	99	125	25.42
	old-13-25B	25.84	4.49	2/27/2004	23.40	29.64	6.24	91	125	33.67
	old-13-24A	14.2	4.19	2/27/2004	21.98	29.64	7.66	135	125	-9.83
	old-13-33A	14.27	5.61	2/27/2004	19.75	29.64	9.89	327	125	-202.53
	old-13-34B	28.7	5.73	2/27/2004	22.88	29.64	6.76	46	125	78.92
Wells slightly away from lake shore	old-13-22B	35.65	3.88	2/26/2004	23.69	29.64	5.95	117	125	7.33
	old-13-12A	14.08	4.38	2/27/2004	19.87	29.64	9.77	205	125	-80.67
Wells midway from lake shore to bldg 1100 site	old-13-43C	49.38	4.53	3/3/2004	24.60	29.64	5.04	143	125	-18.33
	old-13-15A	15.16	4.95	2/26/2004	20.90	29.64	8.74	409	125	-284.67
	old-13-21B	35.29	4.93	2/26/2004	24.07	29.64	5.57	115	125	9.67
Average					22.27	29.64	7.37	168.77	124.67	-44.10

The following lines of evidence indicate that natural attenuation is occurring at AOC-1:

1. Monitoring wells show significant and consistent decreases in the concentration of 1,1-DCE between 1997 and 2003
2. Geochemical parameters at AOC 1 indicate that the aquifer is predominantly aerobic, which is conducive to biodegradation of 1,1-DCE. Additionally, tidal fluctuations in St. Andrews Bay can be expected to cause dilution of groundwater near the discharge point

One potential drawback for MNA at AOC 1 is that 1,1-DCE slightly exceeds the SWCTL in monitoring wells along the shoreline. However, as described in Section 4.3, 1,1-DCE still has a distance to travel vertically upward before it reaches St. Andrews Bay. In wells closest to the bay, the maximum concentration of 1,1-DCE at the shoreline is 5J µg/L, which is only slightly above the Florida SWCTL of 3.2 µg/L.

Since the concentrations of 1,1-DCE are so low, and given the efficiency of aerobic biodegradation combined with dilution caused by tidal fluctuations, it is reasonable to expect that 1,1-DCE would attenuate prior to reaching the bay. To verify this hypothesis, sampling would occur in St. Andrews Bay to determine the location of groundwater discharge and measure contaminant concentrations, if any, at the discharge locations. Thus, MNA is a feasible alternative for AOC 1 (Southern Division Naval Facilities Engineering Command, 2004).

As a first step in the MNA alternative, Coastal Contamination Migration Monitoring (Trident probe and UltraSeep technologies) would be used to determine whether 1,1-DCE is actually discharging into St. Andrews Bay at levels above the SWCTL of 3.2 µg/L. A protocol for coastal monitoring has been developed and described by SPAWAR Systems Center (SSC San Diego) and the NFESC (NFESC, 2003). The coastal monitoring would be used as a one-time event to determine the zone of groundwater discharge into St. Andrews Bay, and the level of contamination, if any, in the discharge. Based on work at other sites, it is expected that the coastal monitoring would involve the following steps:

1. Screen the site for areas of potential groundwater discharge using a temperature/conductivity/porewater probe (Trident probe). Conductivity and temperature measurements can be used to distinguish groundwater and surface water based on salinity and temperature differences. Water samples would be collected with the Trident probe during the screening survey. These samples would be analyzed on-site for standard water quality characteristics, and a sub-sample would be provided for VOC analysis. The screening would be done along a series of transects extending offshore from the identified area of the 1,1-DCE plume. Trident probe validation samples would be collected using piezometers.
2. If VOCs are detected above the SWCTLs with the Trident probe survey, follow-up sampling would be performed using the ultrasonic multi-sample seepage meter (UltraSeep meter) in the areas of most concern. This sampling would provide more detailed information on the flow mechanism that is driving the migration at the interface, the flow rates, and the actual concentrations that are emerging into the surface water. UltraSeep validation samples would be collected using piezometers.
3. In addition, surface water will be sampled for 1,1-DCE in the area adjacent to monitoring wells PCY-13-17 and PCY-13-18 to determine if the surface water standard may be exceeded. Monitoring well PCY-13-18 will be re-sampled to determine if the bis(2-ethylhexyl)phthalate could be related to contamination from the lab.

4. If the Coastal Contamination Migration Monitoring found that 1,1-DCE was not discharging to the bay in excess of the SWCTL, groundwater monitoring of existing wells would be used to assess the ongoing effectiveness of natural attenuation. Monitoring would occur quarterly for the first year, and annually each subsequent year. Samples would be collected from PCY-13-12I, PCY-13-14I, PCY-13-17S, PCY-13-17I, PCY-13-17D, PCY-13-18S, PCY-13-18I, and PCY-13-18D. These wells were chosen because the groundwater sampling from 2002 and 2003 indicated that 1,1-DCE exceeded its SWCTL of 3.2 µg/L in these locations, although not necessarily at all depths.

The exit strategy would include continued monitoring the eight permanent wells at AOC1 for 5 years, or until the measured concentration of 1,1-DCE dropped below the SWCTL in the eight wells listed above, for monitoring events spanning a 1-year period. After 5 years, if concentrations of 1,1-DCE continue to exceed the SWCTL, then alternative remedies may be considered. Compared with the other alternative (biosparging), MNA would also have the following advantages:

- Essentially no remediation wastes
- No intrusive equipment or piping on site, which is particularly important since the presence of the archaeological site may impact the implementability of biosparging.
- The MNA cost would be significantly lower than biosparging, as the present worth cost for MNA is estimated to be \$184,000 versus \$362,000 for biosparging.

Thus, the present recommended corrective measure for the site is MNA, subject to validation using the Trident probe and UltraSeep technologies.

3.3.3.2 NTC Orlando

Current operations at the site included operation of a groundwater extraction and treatment system to mitigate migration of contaminated groundwater to Lake Druid. This treatment system was planned to run while source remediation alternatives are being developed and implemented, and until these techniques can reduce contaminant concentrations to levels where natural attenuation (NA) and the phytoremediation plantation can effectively control the contaminant plume and remediate groundwater to target levels. The groundwater extraction and treatment system had operated since January 2001 and the phytoremediation plantation was established in March 2002. The in situ chemical oxidation (ISCO) system, which operated from March 2003 to October 2003, was dismantled prior to the demolition of Building 1100.

During the field work for this study, the extraction and treatment system was turned off approximately 1 month prior to sampling. The primary reason was to evaluate, with this sampling, the natural groundwater state without the benefit of the extraction system. The technology demonstration would assess if the extraction and treatment system had been effective in reducing VOC levels and if it is necessary to continue operation. Without the system in operation, groundwater gradient would most likely be greater towards the lake, with more seepage available for measurement.

As described above, significant baseline data existed based on an IR investigation in 2001 and monitoring well sampling in 2004. This data set provided the basis for evaluating the effectiveness of the Trident probe and UltraSeep technologies in assessing natural attenuation between the shoreline wells and the groundwater–surface water interface.

3.4 PRE-DEMONSTRATION TESTING AND ANALYSIS

3.4.1 NSA Panama City

As described above, significant baseline data existed based on a DPT investigation in 2001 and monitoring well sampling in 2002 and 2003. This data set provided the basis for evaluating the effectiveness of the Trident probe and UltraSeep technologies in assessing natural attenuation between the shoreline wells and the groundwater–surface water interface.

3.4.2 NTC Orlando

As described above, significant baseline data existed based on an IR investigation in 2001 and monitoring well sampling in 2004. This data set provided the basis for evaluating the effectiveness of the Trident probe and UltraSeep technologies in assessing natural attenuation between the shoreline wells and the groundwater–surface water interface.

3.5 TESTING AND EVALUATION PLAN

3.5.1 Demonstration Set-up and Start-up

Demonstration preparation included logistics, sampling system decontamination, and system setup. Logistics included coordinating the demonstration with the Navy site personnel, ensuring that the surface vessel is properly equipped with all necessary equipment (including sampling equipment), and coordinating the demonstration schedule with all appropriate personnel and authorities. System decontamination and setup included various tasks to be performed on the Trident probe and UltraSeep prior to deployment as described below.

3.5.1.1 Trident Probe

System setup for the Trident probe is described in detail in Chadwick et al., 2003b and the operations manual (Appendix A). The primary tasks included the following:

Setup AGIS. AGIS is the geographical information system software that is used to display the Trident probe temperature and conductivity results in real time. Setup for the AGIS system is described in detail in the TridentTalk manual (Appendix A). The setup requires importing a map for the study area, setting up the proper coordinate system, and associating the map with the sensor data files of interest.

Test system. System testing for the Trident probe consists of connecting the probe and GPS units to the deck unit, connecting the deck unit to the laptop, and running the system to ensure all the components are operational. This includes the temperature sensors, the conductivity sensors, the GPS, the deck unit, and the laptop.

Sensor calibration. After determining that the system is operational, the calibrations for the temperature and conductivity sensors must be verified. If the sensors are out of calibration, a new calibration must be performed. For the conductivity sensors, the calibration consists of immersing the sensors in known conductivity standards, recording the raw conductivity signals, determining the regression coefficients for the sensor, and inputting the coefficients into the setup of TridentTalk. The procedure for the temperature sensors is similar, but a temperature bath and a precision calibrated digital thermometer are used to establish the known temperature conditions. The GPS requires no calibration.

Pre-clean water sampler. The water sampling probe and all auxiliary sampling equipment must be pre-cleaned using the appropriate solutions for the chemicals that will be analyzed. For the both demonstrations, the samples will be analyzed for VOCs. The pre-cleaning procedure is as follows:

- Remove surface residuals immediately; clean water sampling components (syringes, fittings, tubing, probes, etc.) as soon as possible, rinsing the items with hot/warm detergent
- Hot/warm soak to loosen and float most particulate material; use a 1% Alconox® detergent solution (10 g/L) in water of 50 °C or higher^{a, b}
- Hot tap water rinse to flush away floated particulates^{a, b}
- Distilled water double-rinse to remove trace deposits from tap water; use 18-MΩ deionized (DI) (organic-free) water^{a, b}
- Prior to use, store sampling equipment in clean area; cap the fittings and isolate smaller items, especially the sampling ports on the probe tips, with protective covering (Teflon® or aluminum foil); the glass sample syringes are dried at 100 °C (drying oven) before storage in Teflon® or aluminum foil wrap; before use, rinse probe tips and sample syringe with 18-MΩ deionized (organic-free) water and air-dry.

Note

- a. Flush, soak, rinse, and wash glass sample syringes separately.
- b. For the probes, Y-valves, and fittings, a flow-through system with a peristaltic pump is used to move the hot detergent solution, warm tap water washes and DI water rinses through multiple times for 5 minutes.

Sample containers. Obtain proper sample containers for the chemicals to be analyzed; for the NSA Panama City demonstration, the required containers are 40 ml, pre-cleaned, pre-acidified VOA vials; a minimum of two replicates are required for each sample.

Sampling equipment. Gather all required sampling equipment, including custody sheets, labels, log books, ice chests, Trident probe, and ancillary equipment (follow checklist in Chadwick et al., 2003b).

3.5.1.2 UltraSeep

System set-up for the UltraSeep is described in detail in Chadwick et al. (2003b) and the operations manual (Appendix A). The primary tasks included the following :

Test system. System testing for the UltraSeep consists of connecting the system to the laptop and running the system ensure all the components are operational. This includes the flow meter, temperature sensor, conductivity sensor, sample pump, sample valve, and the laptop.

Sensor calibration. After determining that the system is operational, the calibrations for the flow meter, temperature, and conductivity sensors must be verified. If the sensors are out of calibration, a new calibration must be performed. For the conductivity sensors, the calibration is as described above for the Trident probe. For the flow meter, calibration consists of two steps. The flow meter is first zeroed by filling the flow tube with still water and running the zeroing procedure on the flow meter through the laptop. The flow meter is then calibrated over the expected flow range using a constant head tank, a precision metering valve, and a graduated cylinder.

Pre-clean water sampler. The water sampling probe and all auxiliary sampling equipment must be pre-cleaned using the appropriate solutions for the chemicals that will be analyzed. For both demonstrations, the samples will be analyzed for VOCs. The pre-cleaning procedure is as described above for the Trident probe.

Sample containers. Obtain proper sample containers for the chemicals to be analyzed. For the NSA Panama City demonstration, the required containers are 40 ml, pre-cleaned, pre-acidified VOA vials. A minimum of two replicates is required for each sample.

Sampling equipment. Gather all required sampling equipment, including custody sheets, labels, log books, ice chests, UltraSeep, and ancillary equipment (follow checklist in Chadwick et al., 2003b).

3.5.2 Period of Operation

The Trident probe survey commenced 9 August 2004 and extended to 15 August 2004. The UltraSeep survey commenced 16 August 2004 and extended to 22 August 2004.

3.5.2.1 Amount/Treatment Rate of Material to be Treated

No material was treated during this demonstration because the technology to be demonstrated is not a treatment system. However, where the technology demonstrates that MNA is a viable corrective measure, a substantial active treatment effort may be avoided at the site.

As shown in Figure 3-8, the lateral extent of the 1,1-DCE plume as it approaches St. Andrews Bay was approximately 250 ft. The offshore extent of the plume was not known, but based on a visual extrapolation of the cross section shown in Figure 3-4), it was estimated to extend about 500 ft beyond the shoreline. Thus, the offshore area examined in St. Andrews Bay encompassed approximately 125,000 ft² (2.9 acres). The initial sampling density for the Trident probe survey included approximately five offshore transects with six stations each for a total of 30 stations. Based on previous experience, maximum discharge is most likely to occur during the falling tide, a window of about 8 to 10 hours given the diurnal nature of the tides in St Andrews Bay. Thus, for a sampling rate of about 30 min/station, the Trident probe survey was targeted to be completed within two consecutive ebb tide sampling periods.

3.5.3 Residuals Handling

The only expected residual water generated during the demonstration was the purge water from the Trident probe water sampler and the purge water from the validation micro-wells. The total volume expected was <5 L and the contamination levels were generally very low. Arrangements were made with the on-site contractor to dispose of the residuals using their existing protocols for the monitoring wells at the site.

3.5.4 Operating Parameters for the Technology

3.5.4.1 Trident Probe

The Trident probe is used in a survey mode of operation. The general operating requirements and parameters for the probe relate to the following categories:

Mobilization. Mobilization includes the testing, calibration, cleaning, packing, and shipment of the Trident probe and verification equipment. The mobilization phase for the Trident probe equipment generally requires the labor of two qualified technicians for period of 3 to 5 days, with oversight from the PI. An additional 1 to 2 days will be required for the mobilization of the verification equipment. Shipment of the equipment will require 5 to 7 days from the shipment date to the time of arrival.

Field operations. Field operations include wading or small-boat deployment (depending on water depth), direct-push of the probe, sensor sampling, water sampling, and cleaning the water sampler between stations. Field operations generally require the labor of two qualified technicians, the quality assurance (QA) officer, and the PI for a period that depends on the size of the site, the number of stations, and the hydrogeologic conditions at the site. A typical site may require 5 to 7 days to complete the field operations.

Verification sampling. Verification sampling is not a routine component of the Trident probe operation, but will be included as a vital part of the demonstration. Verification sampling will consist of installation and water sampling from piezometers installed at a subset of the Trident probe stations. The installation will be performed prior to the Trident probe survey and is estimated to require 1 to 2 days for two qualified technicians with PI oversight.. The sampling will be conducted during the Trident probe survey and is included in the 3- to 5-day estimate for the overall field operation of the Trident probe. The water sampling of the piezometers will require the same personnel as the Trident probe field operation.

Demobilization. Demobilization of the Trident probe consists of cleaning, packing, and return shipping the equipment. The demobilization phase is expected to take 2 days for two qualified technicians, with oversight from the PI. Return shipment of the equipment will require 5 to 7 days from the shipment date to the arrival time.

3.5.4.2 UltraSeep

The UltraSeep is used in a survey mode of operation. The general operating requirements and parameters for the probe relate to the following categories:

Mobilization. Mobilization includes the testing, calibration, cleaning, packing, and shipment of the UltraSeep and verification equipment. The mobilization phase for the UltraSeep equipment generally requires the labor of two qualified technicians for a period of 3 to 5 days, with oversight from the PI. An additional 1 to 2 days will be required for the mobilization of the verification equipment. Equipment shipment will require 5 to 7 days from the shipment date to the arrival time.

Field operations. Field operations include wading, diving, and/or small-boat deployment (depending on water depth), UltraSeep installation, sensor sampling, water sampling, and cleaning the water sampling system between deployments. Field operations generally require three qualified technicians (dive certified, if necessary), the QA officer, and the PI for a period that depends on the size of the site, the number of stations, and the hydrogeologic conditions at the site. A typical site may require 5 to 7 days to complete the field operations.

Verification sampling. Verification sampling is not a routine component of the UltraSeep operation, but will be included as a vital part of the demonstration. Verification sampling will consist of installation and sampling from piezometers installed at the UltraSeep stations. The installation will be performed prior to the UltraSeep survey and is estimated to require 1 to 2 days for two qualified technicians with oversight from the PI. The sampling will be conducted during the UltraSeep survey and is included in the 3- to 5-day estimate for the overall UltraSeep field operation. The piezometer sampling will require the same personnel as the Trident probe field operation.

Demobilization. Demobilization of the UltraSeep probe consists of cleaning, packing, and return shipping the equipment. The demobilization phase is expected to take 2 days for two qualified technicians, with oversight from the PI. Return shipment of the equipment will require 5 to 7 days from the shipment date to the arrival time.

3.5.5 Experimental Design

The experimental designs for the demonstration and validation of the Trident and UltraSeep technologies at NSA Panama City and NTC Orlando were based on the Conceptual Site Models (CSMs) developed for the demonstration. Details of the CSMs are described in Subsections 3.5.5.1 and 3.5.5.2.

3.5.5.1 CSM Panama City

Figures 3-1 through 3-7 show site maps of AOC 1 at NSA Panama City, including the offshore area in St. Andrews Bay, the historical monitoring well and DPT sampling locations, and the approximate known extent of the current 1,1-DCE plume. The site is located on the St. Andrews Bay shore, approximately 6 miles east of Panama City, Florida (Figure 3-13). The offshore area encompasses a shallow region in the northern reach of St. Andrews Bay, with depths generally ranging from 3 ft to less than 1 ft (Figure 3-14). Soils and sediments underlying the site and in the offshore area are composed primarily of sand. The primary contaminants of concern are VOCs, in particular, 1,1-DCE.

For 1,1-DCE, the DPT investigation in 2001 and monitoring well sampling in 2002 and 2003 showed exceedences near St. Andrews Bay of the Florida Marine SWCTL of 3.2 µg/L. The DPT investigation indicated that 1,1-DCE is completely depleted in the source zone, but it has migrated laterally to the edge of St. Andrews Bay at concentrations slightly above the SWCTLs. However, the 1,1-DCE exceedences occur at 10 to 30 ft below the water table, such that further migration (vertically upward) is required before contamination would discharge into the surface water of the bay.

Since there are no wells or DPT locations in the bay, it is unknown where the discharge to surface water would occur. Theoretically, the contaminants could possibly attenuate (through biodegradation, dilution, and dispersion) prior to reaching surface water, especially since the source has been eliminated, and the measured concentrations are close to the SWCTL (Southern Division Naval Facilities Engineering Command, 2004).

A basic CSM for VOC migration to St. Andrews Bay is shown in Figure 3-15. The migration pattern of VOCs toward St. Andrews Bay is consistent with the measured hydraulic gradient in the area. The plume would be expected to migrate vertically upward as it approaches the bay, due to the lower density of the fresh groundwater versus the higher density of the saline bay water. It is also expected that the concentrations will decrease due to the combined effects of flow and tidally induced dispersion and biodegradation.

3.5.5.2 CSM-Orlando

Figures 3-8 through 3-12 show site maps of OU 4 NTC Orlando, including the Lake Druid historical monitoring well and PCE sampling locations, and the approximate known extent of the current VOC plume. Figure 3-16 shows a basic CSM for VOC migration to Lake Druid. The VOC migration pattern towards Lake Druid is consistent with the measured hydraulic gradient in the area before and after operation of the extraction and treatment system began (Figures 3-17 and 3-18). The site is located on the east shore of Lake Druid in Orlando (Figures 3-19 through 3-21). Lake depths in the sampling area range from 0 ft. along the shoreline and increase gradually to approximately 8 ft. on the western edge of the footprint. Lake depths continue to about 15 ft.

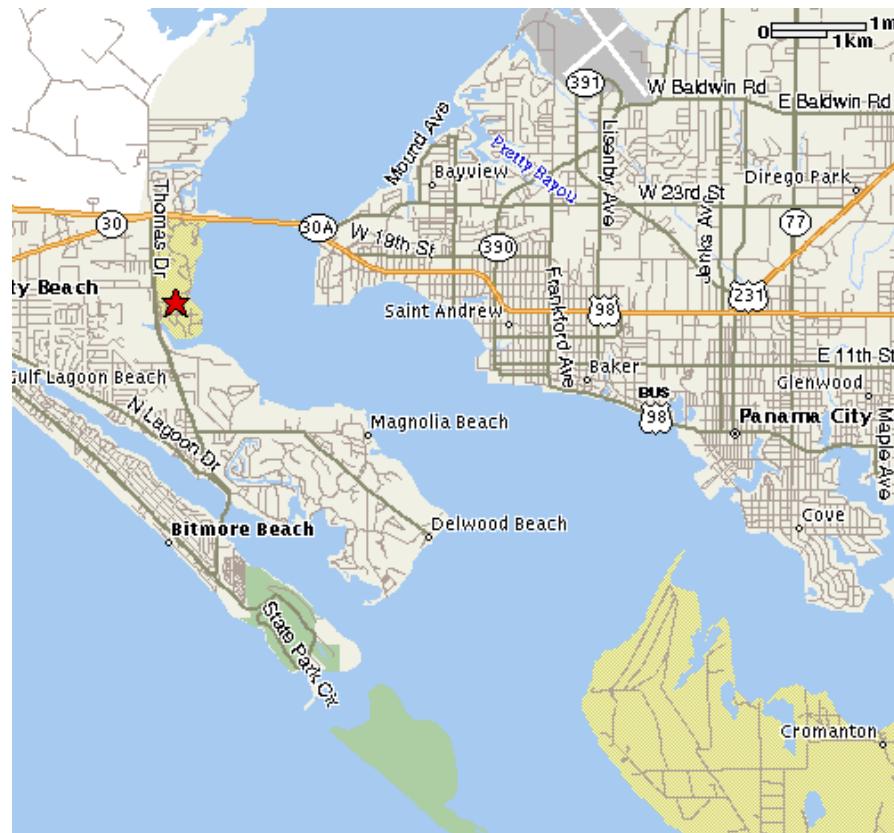


Figure 3-13. Location map for Trident/UltraSeep demonstration at NSA Panama City.

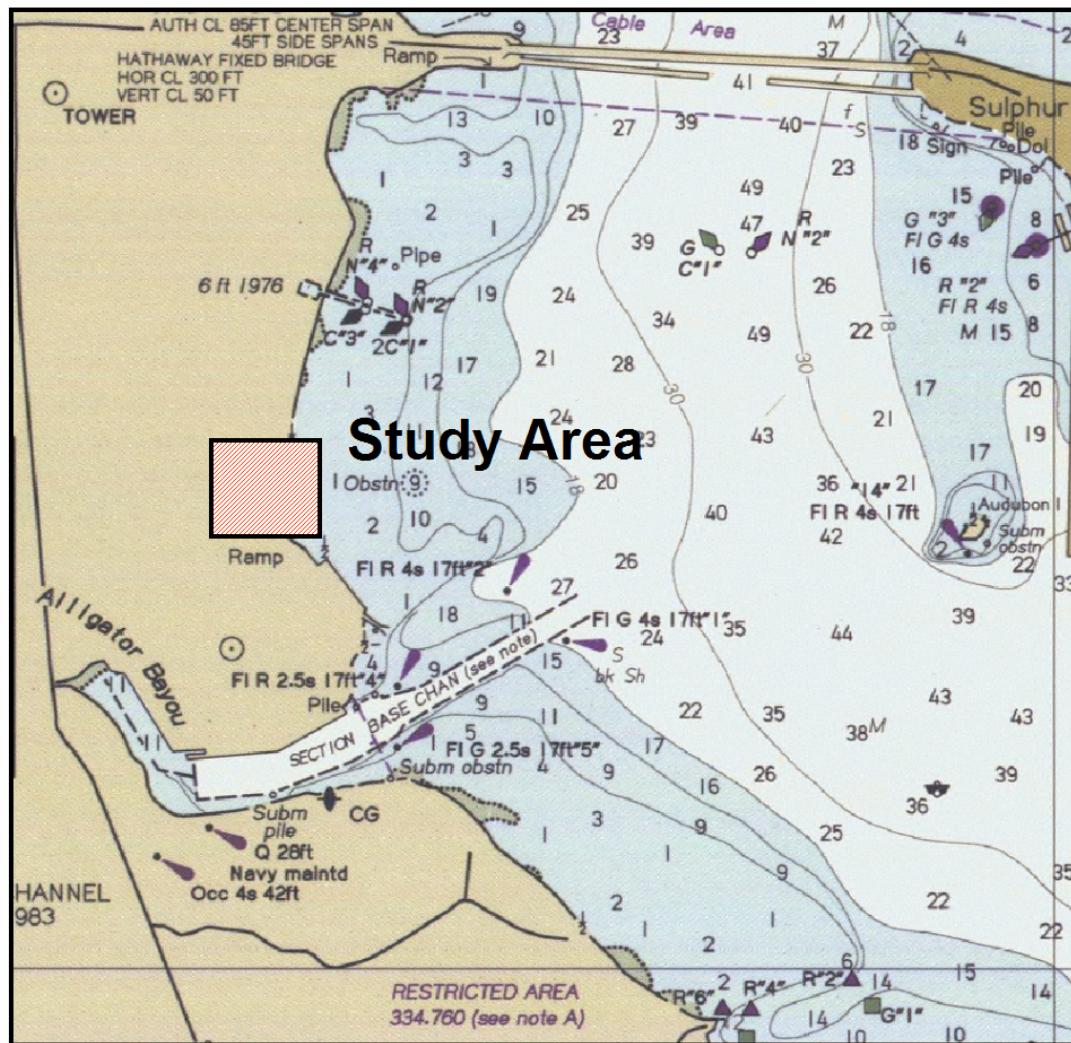


Figure 3-14. Bathymetric chart showing offshore topography at NSA Panama City site.

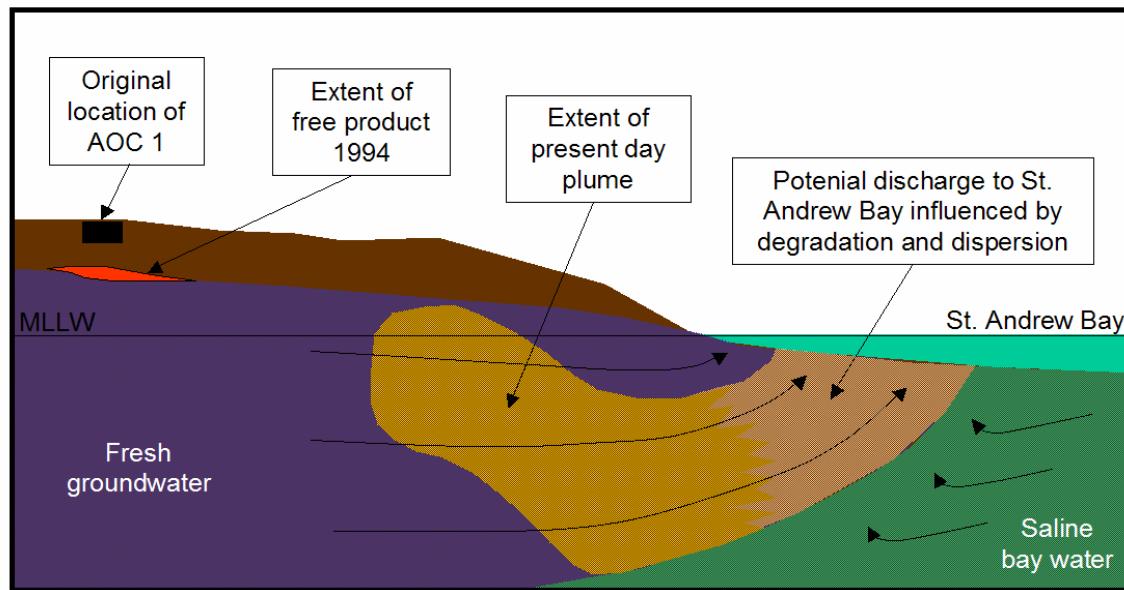


Figure 3-15. CSM for AOC 1 in relation to potential discharge of VOCs to St. Andrews Bay.

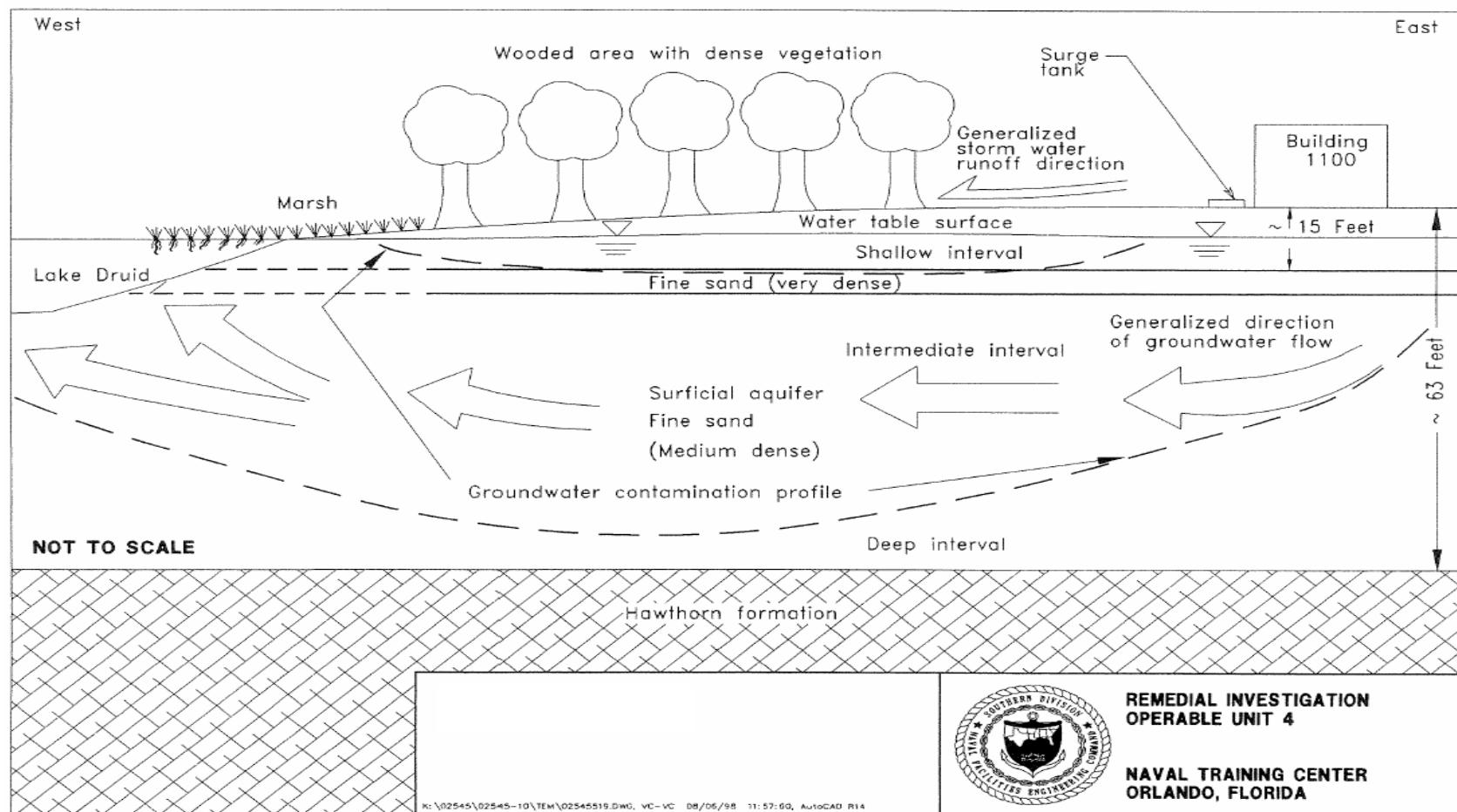


Figure 3-16. CSM for VOC migration to Lake Druid.
(from Southern Division Naval Facilities Engineering Command, 2001)

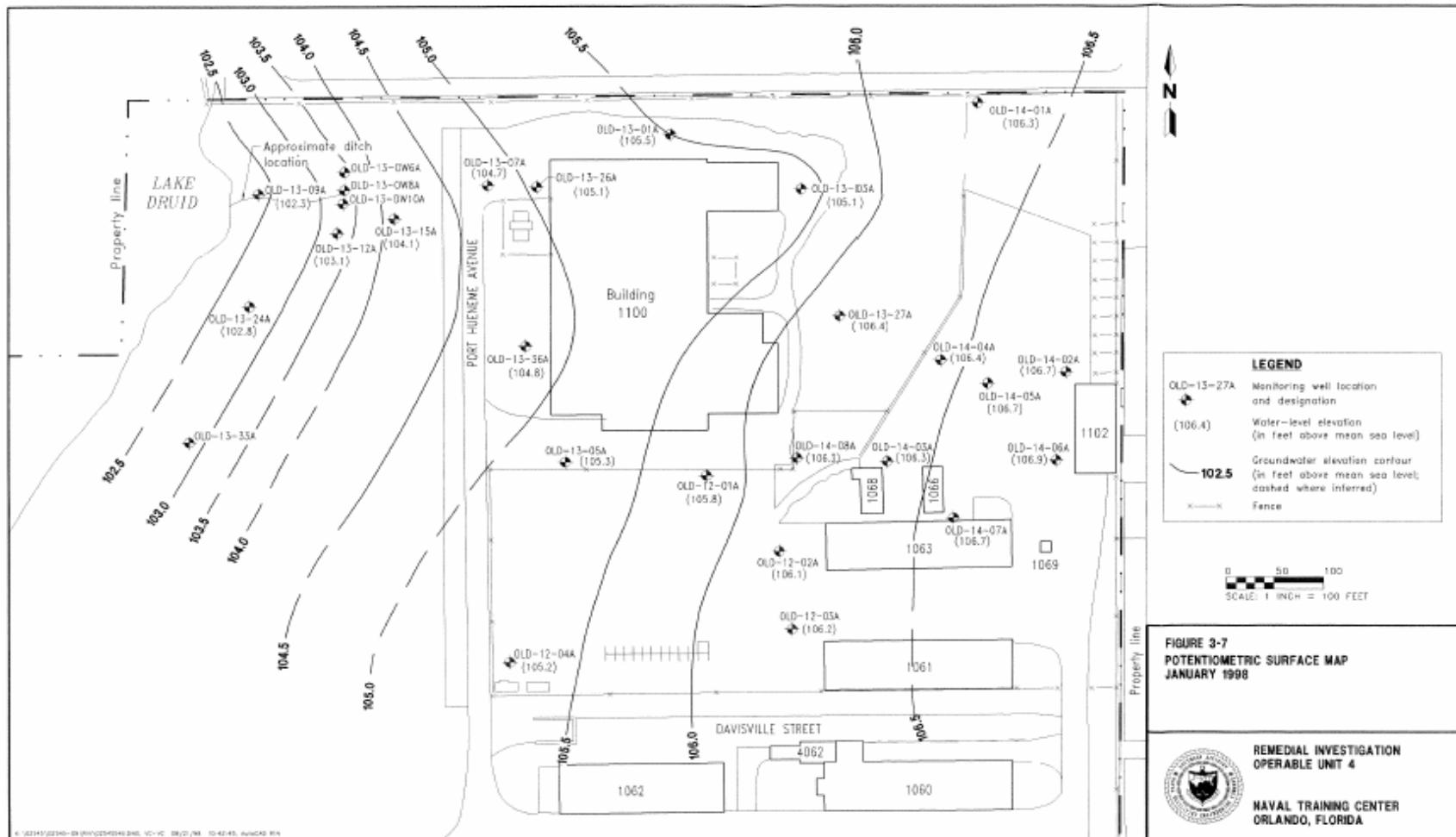
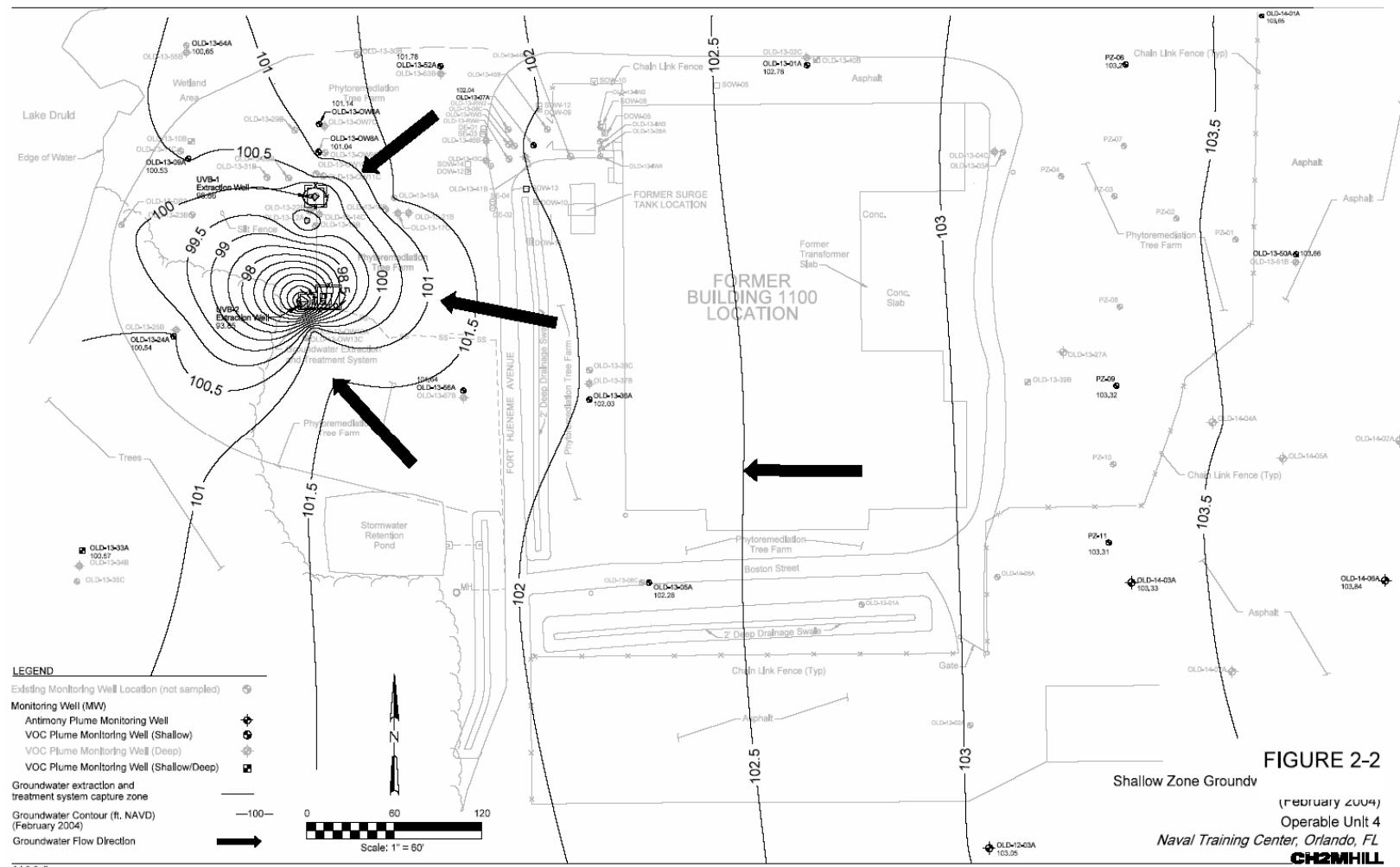


Figure 3-17. Groundwater elevation map as of January 1998 prior to installation of groundwater extraction system.
(from Southern Division Naval Facilities Engineering Command, 2001)



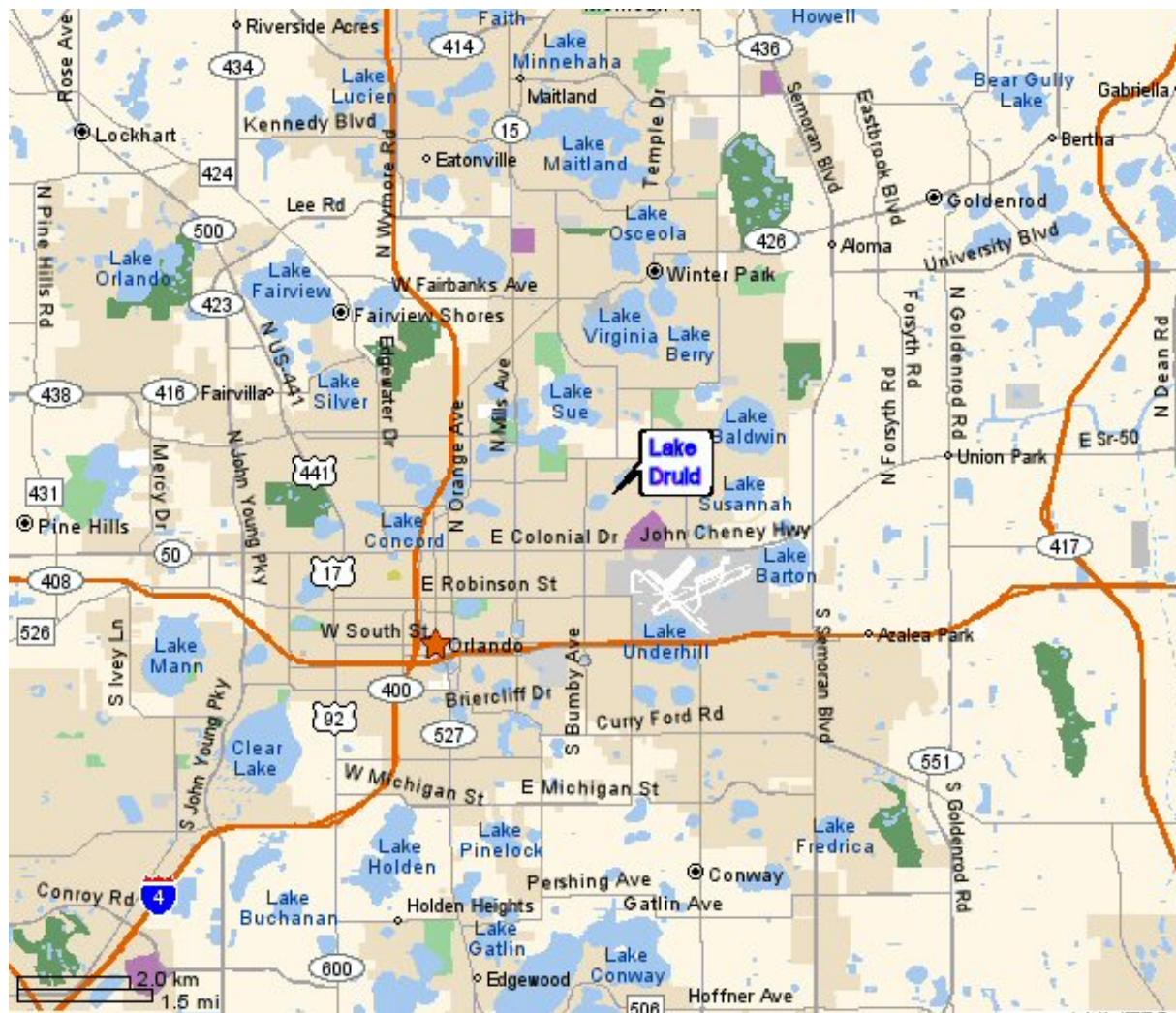


Figure 3-19. Lake Druid in relation to downtown Orlando, Florida.



Figure 3-20. Aerial photograph of Lake Druid. Bordered in blue is the study area depicted in Figure 3-23.



Figure 3-21. Designated offshore study area in Lake Druid for the NTC Orlando Demonstration.

The contaminants of concern are primarily VOC, particularly PCE and its degradation products, introduced into the soil over many years from a dry-cleaning activity. A large source deposit of contamination was found during the Site Screening Survey in 1995 directly beneath the dry-cleaning facility, and subsequent groundwater sampling has found migration of this contamination westerly towards Lake Druid and downward into the lower Hawthorn Group of sediments ranging in depth from 60 to 110 ft (CH2M Hill, 2005).

3.5.6 Sampling Plan

Well-designed and accurate data collection and analysis to confirm the technology performance on the target contaminant provided the basis for regulatory reviews and evaluations of the Trident and UltraSeep technologies. ESTCP and the regulatory community will use data generated by the demonstration projects to verify the costs and performances of the technologies demonstrated.

The sampling plans for the demonstration and validation of the Trident and UltraSeep technologies at NSA Panama City and NTC Orlando are encompassed in the Data Quality Objectives (DQOs) developed for the demonstrations. Sampling procedures associated with these DQOs are described in the demonstration's Quality Assurance Project Plan (Appendix C). Details of the DQOs are described in Subsections 3.5.6.1 through 3.5.6.7.

3.5.6.1 Data Quality Objectives—NSA Panama City

Step 1. State the Problem:

Groundwater contaminated with VOCs at AOC 1 is migrating towards St. Andrews Bay and may pose an unacceptable environmental risk. Additional data are needed to determine if significant attenuation is occurring prior to groundwater and associated VOCs discharging to the bay, and to verify that MNA is a viable corrective action for the site.

Step 2. Identify the Decision:

- Are VOCs discharging to St. Andrews Bay from AOC 1 at levels that pose an unacceptable risk to the environment?
- Are natural processes effectively attenuating the VOCs before they reach St. Andrews Bay?

Step 3. Identify the Inputs to the Decision:

- Existing site-specific monitoring well and DPT data on the horizontal and vertical distribution of VOCs in groundwater between AOC 1 and the shoreline of St. Andrews Bay
- Horizontal Trident probe mapping of conductivity and temperature contrast at the groundwater–surface water interface in St. Andrews Bay
- Horizontal Trident mapping of VOCs at the groundwater–surface water interface in St. Andrews Bay
- Continuous UltraSeep discharge measurements of groundwater to St. Andrews Bay over a complete tidal cycle
- Flow-proportional UltraSeep sampling of groundwater discharge to St Andrews Bay
- Measurement of surface water concentrations of VOCs in St. Andrews Bay

- Verification water levels and VOC concentrations in piezometers installed at a subset of stations

Step 4. Define the Boundaries of the Study:

- The offshore study area is bounded by the shoreline to the west, and by the documented extent of the plume to the north and south. Although the offshore extent of the plume is unknown, hydrogeologic conditions suggest that the plume is most likely to discharge near the shoreline.
- The lower vertical limit of the offshore study area is 2 to 3 ft below the sediment/water interface because this is the design depth of the Trident probe and is also a reasonable lower limit for biological activity related to the sediment and surface water.

Step 5. Develop a Decision Rule:

- Trident subsurface temperature/conductivity contrast. Horizontal Trident mapping of conductivity and temperature contrast at the groundwater–surface water interface in St. Andrews Bay will be used to identify likely areas of groundwater discharge to St. Andrews Bay. It is expected that during the summer, the groundwater will be colder and fresher than the surface water. Thus, areas in the sediment having these interstitial water characteristics will be identified as likely areas of groundwater discharge. If no areas of temperature/conductivity contrast can be identified, then it will be concluded that the point of discharge is too diffuse to be isolated.
- Trident subsurface VOC water sampling. Horizontal Trident mapping of VOCs at the groundwater–surface water interface in St. Andrews Bay will be used to identify potential environmental risk relative to media protection standards and to determine the extent of natural attenuation between the shoreline wells and the point of release to St. Andrews Bay. If Trident subsurface VOC samples are below the SWCTL, then it will be concluded that natural processes are attenuating the VOC plume such that no risk to the environment exists. If Trident subsurface VOC samples exceed the SWCTL, then it will be concluded that potential risk to the environment is present, and UltraSeep water samples will be collected to determine the actual concentration and mass loading of VOCs discharging to the bay.
- UltraSeep groundwater discharge quantification. Continuous UltraSeep discharge measurements of groundwater to St. Andrews Bay over a complete tidal cycle will be used to quantify the mean and tidal components of the discharge rate. A positive mean discharge rate is an indicator that groundwater is discharging to the bay at that location. The strength of the tidal component of the discharge will be used to assess the influence of surface water mixing within the sediments.
- UltraSeep VOC discharge quantification. Flow-proportional UltraSeep sampling of groundwater discharge to St. Andrews Bay to determine the concentration and mass of VOCs discharging to the bay. If UltraSeep VOC discharge concentrations are below the SWCTL, then it will be concluded that natural processes are attenuating the VOC plume such that no risk to the environment exists. If UltraSeep VOC discharge concentrations exceed the SWCTL, then it will be concluded that potential risk to the environment is present and surface water concentrations will be measured to determine the extent of the risk.
- Quantification of surface water VOCs: Measurement of surface water concentrations of VOCs in St. Andrews Bay will be used to determine if groundwater discharge from

AOC 1 is leading to detectable increases in surface water concentrations for VOCs. If Trident probe and UltraSeep data indicate significant VOC discharge to surface water, surface water concentrations will be used to determine the extent of potential risk to the environment. If Trident and UltraSeep data indicate limited or no discharge of VOCs, surface water concentrations will be used to validate the absence of risk.

- Piezometer water levels and VOCs. Water levels and VOC concentrations in piezometers installed at a subset of stations will be used to validate the Trident/UltraSeep results. Because the Trident/UltraSeep are new technologies, it is important to provide an independent validation of the results using a previously accepted technology. If the water levels in the piezometers indicate a positive vertical hydraulic gradient in the piezometers, this indicator would validate a measured positive discharge rate in the UltraSeep. Presence or absence of VOCs in the groundwater sampled will serve as verification of the Trident/UltraSeep VOC sample results.

Step 6. Evaluate Decision Errors:

An erroneous assessment of the magnitude and extent of VOC discharge to St. Andrews Bay from AOC 1 could result in incorrect conclusions regarding risk to the environment, which in turn could lead to incorrect conclusions regarding the most optimal corrective action. These errors will be minimized by relying on multiple lines of evidence (Trident probe, UltraSeep, surface water) to characterize VOC fate and transport at the site, and validation using an independent line of evidence (piezometers).

Step 7. Optimize the Design for Obtaining Data:

Characterize fate and transport of VOCs between AOC 1 and St. Andrews Bay in relation to natural attenuation processes and potential environmental risk: These objectives require site-specific data on contaminant fate and transport to support the evaluation of corrective actions. The sample design for these objectives is based on best professional judgment as described below.

- Trident Sampling. Thirty Trident probe stations will be sampled for temperature/conductivity contrast and subsurface VOC water sampling (Figure 3-22). Trident sampling locations are located along five offshore transects extending eastward from the shoreline with six stations each. Alongshore and offshore sample spacing is approximately 100 ft. Trident probe temperature/conductivity and VOC sampling will be performed at approximately 2 ft below the sediment surface, depending on the practical penetration depth of the probe. Trident sampling will be timed to occur during the falling tide, when discharge conditions are most favorable. Sediment samples will be collected at a minimum of five stations for analysis of grain size and TOC to evaluate the influence of porosity and clay content on the Trident probe conductivity readings.
- UltraSeep Sampling. A minimum of three UltraSeep stations will be sampled for specific discharge, VOC discharge and temperature/conductivity of the discharge. Sampling locations for the UltraSeep will be selected in consultation with the site manager based on the Trident probe survey results. The locations will be selected to target areas of the highest water and VOC discharge. UltraSeep measurements will extend over a complete diurnal tidal cycle. UltraSeep water samples will be collected approximately every 2.5 hours, depending on discharge conditions.

- **Surface Water Sampling.** Surface water sampling will be performed at all 30 Trident stations. Surface water will be collected from the water column approximately 1 ft above the sediment surface. Surface water sampling will be timed to occur during the falling tide, when discharge conditions are most favorable.
- **Validation Sampling.** Validation sampling using piezometers will occur along the six central transect stations (T3s), and at the three UltraSeep/surface-water sampling stations. For the Trident validation, piezometers will be installed to 2 ft below the sediment surface. The 2-ft piezometer will be used to collect water samples for validation of the Trident probe results. Water samples from the 2-ft piezometer will be collected at the same time the corresponding Trident probe water sample is collected. For the UltraSeep validation, piezometers will be installed to 1 ft and 3 ft below the sediment surface. The 1-ft piezometers will be used to evaluate the near surface concentration of VOCs that would be discharging to the bay for comparison to discharge samples collected by the UltraSeep. Water levels from the 3 ft piezometers will be recorded on a periodic basis throughout the tidal cycle to determine the vertical hydraulic gradient as a means of validating the direct flow measurements obtained from the UltraSeep.

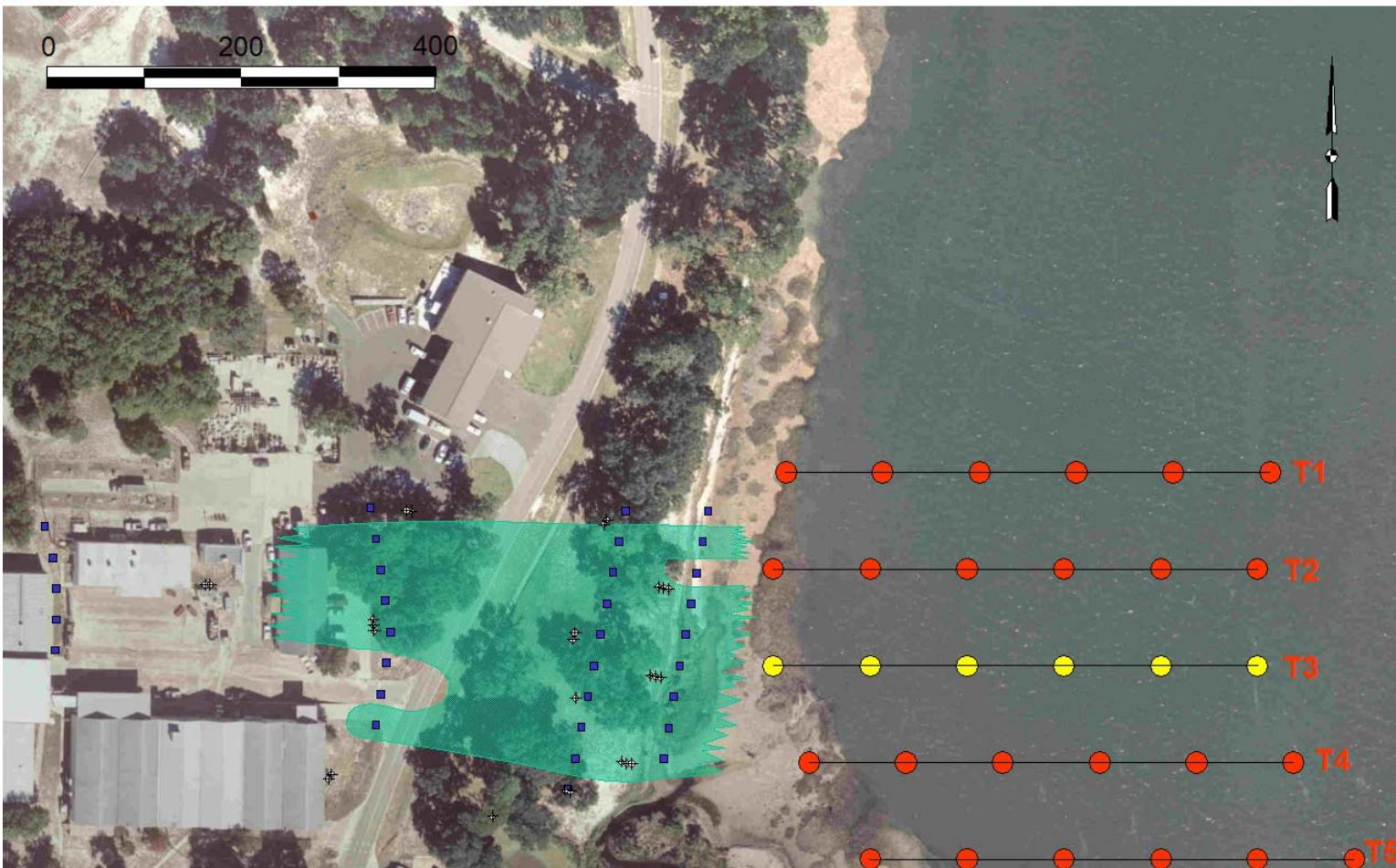


Figure 3-22. Sampling design for the Trident probe survey at NSA Panama City showing historical monitoring wells, DPT locations, approximate location of the 1,1-DCE plume, and proposed offshore transect locations. Red circles indicate stations for Trident probe and surface water sampling, and yellow circles indicate stations for Trident probe, surface water, and validation sampling.

3.5.6.2 Data Quality Objectives—NTC Orlando

Step 1. State the Problem

Groundwater contaminated with VOCs at OU 4 is migrating towards Druid Lake, and may pose an unacceptable environmental risk. The migration is currently controlled by a pump and treat system. Additional data are needed to determine if the pump and treat system has been sufficiently effective in treating the groundwater and that discharge of VOCs will no longer pose an unacceptable environmental risk when the pump and treat system is shut down.

Step 2. Identify the Decision:

- With the pump and treat system shut down, are VOCs discharging to Druid Lake from OU 4 at levels that pose an unacceptable risk to the environment?
- Are natural processes effectively attenuating the remaining VOCs before they reach Lake Druid?

Step 3. Identify the Inputs to the Decision:

- Existing site-specific monitoring well data on the horizontal and vertical distribution of VOCs in groundwater between OU 4 and the shoreline of Lake Druid
- Horizontal Trident probe mapping of temperature contrast at the groundwater–surface water interface in Lake Druid
- Horizontal Trident probe mapping of VOCs at the groundwater–surface water interface in Lake Druid
- Continuous UltraSeep discharge measurements of groundwater to Druid Lake through a 24-hour period
- Flow-proportional UltraSeep sampling of groundwater discharge to Lake Druid
- Measurement of surface water concentrations of VOCs in Lake Druid
- Verification water levels and VOC concentrations in piezometers installed at a subset of stations

Step 4. Define the Boundaries of the Study:

- The offshore study area is bounded by the shoreline to the east, and by the documented extent of the plume to the north and south. Although the offshore extent of the plume is unknown, hydrogeologic conditions suggest that the plume is most likely to discharge near the shoreline.
- The lower vertical limit of the offshore study area is 2 to 3 ft below the sediment/water interface because this is the design depth of the Trident probe and is also a reasonable lower limit for biological activity related to the sediment and surface water.

Step 5. Develop a Decision Rule:

- Trident subsurface temperature/conductivity contrast. Horizontal Trident mapping of conductivity and temperature contrast at the groundwater–surface water interface in Lake Druid will be used to identify likely areas of groundwater discharge to the lake. Groundwater discharge areas are expected to show colder temperatures than surrounding areas and surface waters. Conductivity is not expected to be helpful in this freshwater environment; however, temperature contrasts should be seen.

Areas identified as discharge zones will be targeted for subsequent VOC sampling. If no areas of temperature/conductivity contrast can be identified, then it will be concluded that the point of discharge is too diffuse to be isolated by the Trident probe sensors. In this case, the test will continue with VOC measurements on the general sampling grid (not targeted).

- Trident subsurface VOC water sampling. Horizontal Trident mapping of VOCs at the groundwater–surface water interface in Lake Druid will be used to identify potential environmental risk relative to media protection standards and to determine the extent of natural attenuation between the shoreline wells and the point of release to the lake. Trident samples will be targeted to identified discharge zones, or collected on the general grid if no zones can be isolated. If Trident subsurface VOC samples are below the SWCTL (PCE, 8.85 ppb; TCE, 80.7 ppb; 1,1-DCE, 3.2 ppb), then it will be concluded that the extraction and treatment system and natural processes are attenuating the VOC plume such that no risk to the environment exists. If Trident subsurface VOC samples exceed the SWCTL, then it will be concluded that potential risk to the environment is present, and the UltraSeep water samples will be used to determine the actual concentration and mass loading of VOCs discharging to the lake.
- UltraSeep groundwater discharge quantification. Continuous UltraSeep discharge measurements of groundwater to Lake Druid over a 24-hour period will be used to quantify the mean discharge rate. A positive mean discharge rate is an indicator that groundwater is discharging to the bay at that location. The UltraSeep locations will be selected to coincide with identified discharge zones where elevated VOCs are present. If no discharge zones can be isolated with the Trident, then the UltraSeep measurements will be targeted to areas where elevated VOCs were found on the general sampling grid. If no elevated VOCs are found, then the UltraSeep measurements will be conducted along the central transect of the generalized sampling grid at station 1, 3, and 5.
- UltraSeep VOC discharge quantification. Flow-proportional UltraSeep sampling of groundwater discharge to Lake Druid is made to determine the concentration and mass of VOCs discharging to the lake. If UltraSeep VOC discharge concentrations are below the SWCTL, then it will be concluded that natural processes are attenuating the VOC plume such that no risk to the environment exists. If UltraSeep VOC discharge concentrations exceed the SWCTL, then it will be concluded that potential risk to the environment is present and surface water concentrations will be measured to determine the extent of the risk.
- Quantification of surface water VOCs. Measurement of surface water concentrations of VOCs in Lake Druid will be used to determine if groundwater discharge from OU 4 is leading to detectable increases in surface water concentrations for VOCs. If Trident and UltraSeep data indicate significant VOC discharge to surface water, surface water concentrations will be used to determine the extent of potential risk to the environment. If Trident probe and UltraSeep data indicate limited or no discharge of VOCs, surface water concentrations will be used to validate the absence of risk.
- Piezometer water levels and VOCs. Water levels and VOC concentrations in piezometers installed at a subset of stations will be used to validate the Trident/UltraSeep results. Because the Trident/UltraSeep are new technologies, it is important to provide an independent validation of the results using a previously accepted technology. If the water levels in the piezometers indicate a positive vertical hydraulic gradient in the

water, piezometers would validate a measured positive discharge rate in the UltraSeep. The presence or absence of VOCs in the sampled groundwater will serve as verification of the Trident/UltraSeep VOC sample results.

Step 6. Evaluate Decision Errors:

An erroneous assessment of the magnitude and extent of VOC discharge to Lake Druid from OU 4 could result in incorrect conclusions regarding environmental risk, which in turn could lead to incorrect conclusions regarding the most optimal corrective action. These errors will be minimized by relying on multiple lines of evidence (Trident probe, UltraSeep, surface water) to characterize VOC fate and transport at the site, and validation using an independent line of evidence (piezometers).

Step 7. Optimize the Design for Obtaining Data:

Characterize fate and transport of VOCs between OU 4 and Lake Druid in relation to pump and treat system operation, natural attenuation processes, and potential environmental risk. These objectives require site-specific data on contaminant fate and transport to support the evaluation of corrective actions. The sample design for these objectives is based on best professional judgment as described below.

- Trident Probe Sampling. Twenty-four Trident probe stations will be sampled for temperature/conductivity contrast and subsurface VOC water sampling. Trident probe sampling locations are located along five offshore transects extending westward from the shoreline with five stations each, except transect T5, which has four stations (Figure 3-23). Along shore and offshore, spacing is approximately 50 ft. This grid may be adapted in the field for VOC sampling if the Trident probe sensor data indicate specific groundwater discharge zones. In addition, 10 contingency stations will be included to assess identified discharge zones in more detail, or to expand the sampling grid if the original grid does not completely encompass the discharge zone. The locations of the adapted stations and the contingency stations will be selected by the PI in consultation with the site manager. Trident temperature/conductivity and VOC sampling will be performed at approximately 2 ft below the sediment surface, depending on the practical penetration depth of the probe. Sediment samples will be collected at a minimum of five stations for analysis of grain size and TOC to evaluate the influence of porosity and clay content on the Trident probe conductivity readings.
- UltraSeep Sampling. A minimum of three UltraSeep stations will be sampled for specific discharge, VOC discharge, and temperature/conductivity of the discharge. Sampling locations for the UltraSeep will be selected in consultation with the site manager, based on the Trident probe survey results. The locations will be selected to target areas of highest water and VOC discharge. Alternatively, if no discharge zones are identified with the Trident, these stations will be located along the central transect of the general sampling grid at stations 1, 3, and 5. UltraSeep measurements will extend over a 24-hour period. UltraSeep water samples will be collected approximately every 2.4 hours, depending on discharge conditions.
- Surface Water Sampling. Surface water sampling will be performed at all 24 Trident stations, as well as the 10 contingency stations. Surface water will be collected from the water column approximately 1 ft above the sediment surface.

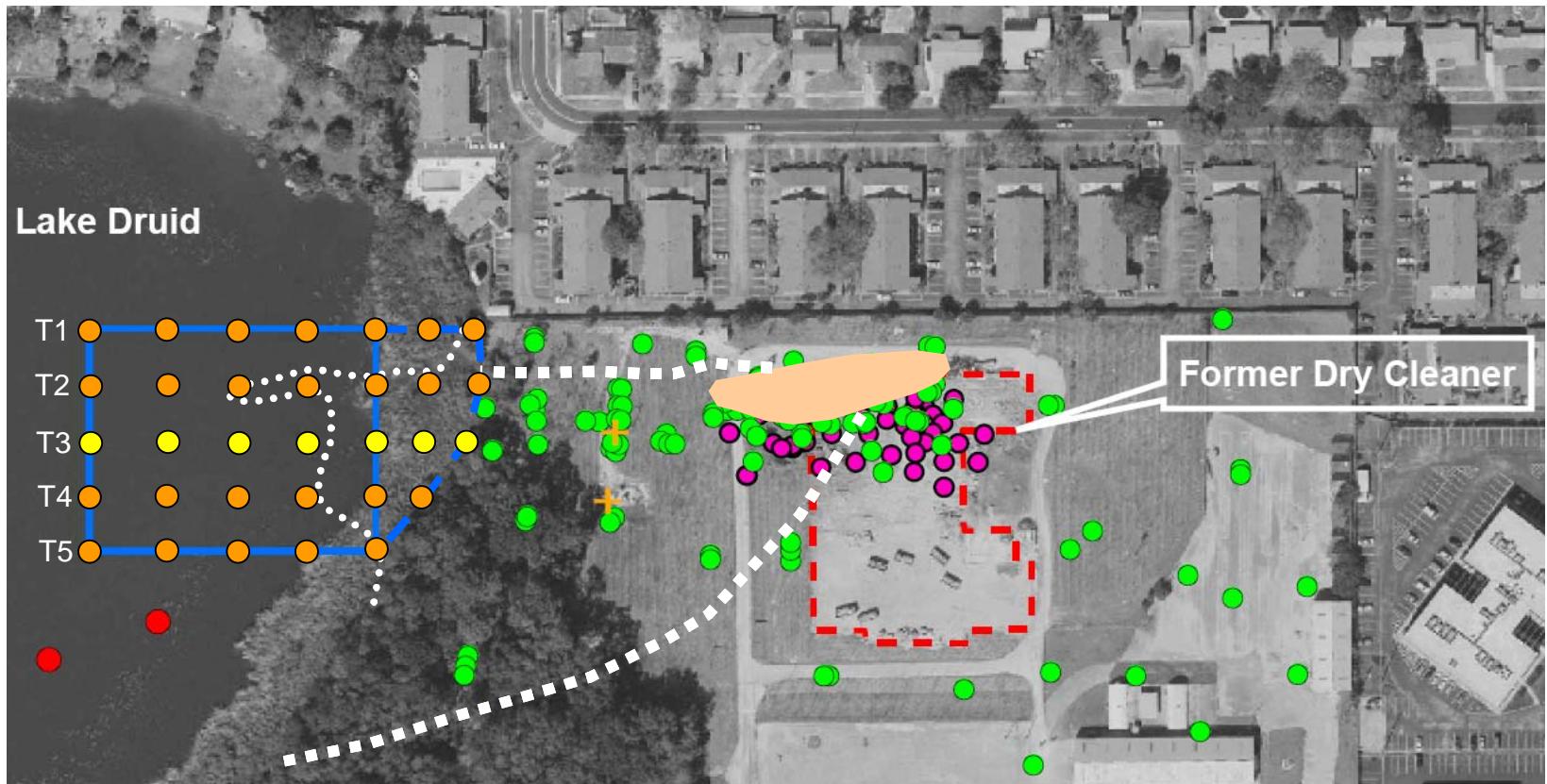


Figure 3-23. The sampling design for the Lake Druid study area. The orange and yellow dots are the proposed Trident probe sampling stations. The yellow dots indicate transect T3, where the validation piezometers will be installed. The filled beige area indicates the approximate location of the original source zone, the white dashed lines indicate the approximate location of the $10 \mu\text{g}/\text{total VOC}$ contour towards Lake Druid (prior to treatment), and the white dotted line indicates the approximate location where VOCs were previously detected in the sediments of the lake (prior to treatment).

- **Validation Sampling.** Validation sampling using piezometers will occur along the six central transect stations, and at the three UltraSeep/surface waters sampling stations. For the Trident validation, piezometers will be installed to 2 ft below the sediment surface. The 2-ft piezometer will be used to collect water samples for validation of the Trident results. Water samples from the 2-ft piezometer will be collected at the same time the corresponding Trident water sample is collected. For the UltraSeep validation, piezometers will be installed to 1 ft and 3 ft below the sediment surface. The 1-ft piezometers will be used to evaluate the near surface concentration of VOCs that would be discharging to the lake for comparison to discharge samples collected by the UltraSeep. Water levels from the 3-ft piezometers will be recorded to determine the vertical hydraulic gradient as a means of validating the direct flow measurements obtained from the UltraSeep.

3.5.6.3 Sample Collection

This subsection discusses Trident probe, UltraSeep, surface water, and validation sample collection.

Trident probe samples. Groundwater for VOC analysis were collected using the Trident water sampling probe connected by 1/16-inch inside diameter Teflon® tubing to an in-line VOA bottle filler (Solinst, Inc.) powered by a low-flow peristaltic pumping system. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) were pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994.

The probe was inserted to 2 ft below the sediment surface using the push-pole system. A Y-valve was used to direct the sample water first to a purging syringe, and then to the sampling system. The purging syringe was used to withdraw approximately 60 ml (an estimated three sampler volumes, assuming a 10-m sample tube), and the sample system was then used to fill two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter (Myron L Company) water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential, and total dissolved solids). The VOA bottles were pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw-cap vials with polytetrafluoroethylene (PTFE)-faced silicone septa.

Between stations, the sampling system was flushed with a sequential series of solutions, including (1) surface seawater, (2) hot RBS® solution, and (3) dionized water. Blanks for the Trident probe survey included equipment rinsate samples and trip blanks. All samples are unfiltered. Care was taken during the pumping process to minimize the amount of suspended solids in the samples.

All VOC samples must be stored on ice at 4 °C prior to shipment and analysis. All samples were individually identified by technology, study, nature, date of collection, and station number. Individual sample identifications were included on the custody sheet that accompanies the sample shipment to the laboratory. Holding time for the VOC samples did not exceed 14 days. Trident sampling was timed to occur during the falling tide, when discharge conditions are most favorable. The Trident survey sampling schedule is shown in Table 3-2 (NSA Panama City) and Table 3-4 (NTC Orlando). All sampling operations were carefully noted in the field log.

In some cases, the Trident probe push met with refusal due to sediment geological conditions or other obstructions. In these cases, the station was relocated by a distance of approximately 1 to 2 m and the push was be repeated. In sediments with relatively high clay content, the Trident probe may be unable to draw water samples. In these cases, the

station was relocated by a distance of approximately 1 to 2 m and the push was repeated. This process was repeated up to three times, at which time if the water sampling was still unsuccessful, the site conditions were noted, and the station was abandoned.

UltraSeep samples. Discharge water samples for VOC analysis were collected using the water sampling system on the UltraSeep. The system draws samples from the seepage funnel to the Teflon® sampling bags via a 1/16-inch inside diameter Teflon® tube using the built-in peristaltic pump. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) were pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994. The UltraSeep was deployed on the bottom, and up to 10 water samples were collected at an interval of about 2.4 to 2.5 hours in proportion to the measured discharge rate. The entire deployment period was about 24 to 25 hours.

Following retrieval of the UltraSeep, the water samples were transferred from the sampling bags to two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential, and total dissolved solids). The VOA bottles were pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw-cap vials with PTFE-faced silicone septa.

Between deployments, the sampling system was re-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994. Blanks for the UltraSeep survey included equipment rinsate samples, and trip blanks. All samples were unfiltered, and all VOC samples were stored on ice at 4 °C prior to shipment and analysis.

All samples were also individually identified by technology, study, nature, date of collection, and station number. Individual sample identifications were included on the custody sheet that accompanied the sample shipment to the laboratory. Holding time for the VOC samples did not exceed 14 days. UltraSeep sampling was timed to occur over a complete diurnal tidal cycle or a complete 24-hour period. The sampling schedule for the UltraSeep survey is shown in Table 3-3 (NSA Panama City) and Table 3-5 (NTC Orlando). All sampling operations were carefully noted in the field log.

In low-discharge environments, it is possible that the volume of discharge water collected by the UltraSeep will be insufficient to meet the analytical requirements. If this is the case, samples will be retained based on the following priority: (1) VOC replicate #1, (2) VOC replicate #2, and (3) water quality sample. Alternatively, sequential samples from the 2.5-hour sampling intervals may be composited to produce sufficient volume. The decision whether to abandon replicates or water quality samples or to composite samples will be made by the PI in the field, based on best professional judgment.

Surface water samples. Surface water samples for VOC analysis were collected using the water-sampling probe on the Trident connected by 1/16-inch inside diameter Teflon® tubing to an in-line VOA bottle filler (Solinst, Inc.) powered by a low-flow peristaltic pumping system. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) were pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994.

Table 3-2. Field schedule for the Trident probe survey, including surface water and validation sampling (NSA Panama City)

Trident Task	Day of CY04								
	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug
Stage Trident									
Stage Trident validation piezometers									
Install Trident validation piezometers									
Conduct Trident survey									
Collect Trident validation samples									
Collect surface water samples									
On-site VOC analysis									
On-site data analysis									
Select UltraSeep stations									
Demobilize Trident									
Demobilize Trident validation equipment									

Table 3-3. Field schedule for the UltraSeep survey validation sampling (NSA Panama City).

UltraSeep Task	Day of CY04								
	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug
Stage UltraSeep									
Stage UltraSeep validation piezometers									
UltraSeep validation piezometers #1									
UltraSeep deployment #1									
UltraSeep validation piezometers #2									
UltraSeep deployment #2									
UltraSeep validation piezometers #3									
UltraSeep deployment #3									
Ship UltraSeep & validation samples									
Demobilize UltraSeep									
Demobilize UltraSeep validation equip.									

Table 3-4. Field schedule for the Trident probe survey, including surface water and validation sampling.

Trident Task	Day of CY05								
	27-Jun	28-Jun	29-Jun	30-Jun	1-Jul	2-Jul	3-Jul	4-Jul	5-Jul
Stage Trident									
Stage Trident validation piezometers									
Install Trident validation piezometers									
Conduct Trident Survey									
Collect Trident validation samples									
Collect surface water samples									
On-site VOC analysis									
On-site data analysis									
Select UltraSeep stations									
Demobilize Trident									
Demobilize Trident validation equipment									

Table 3-5. Field schedule for the UltraSeep survey validation sampling.

UltraSeep Task	Day of CY05								
	3-Jul	4-Jul	5-Jul	6-Jul	7-Jul	8-Jul	9-Jul	10-Jul	11-Jul
Stage UltraSeep									
Stage UltraSeep validation piezometers									
UltraSeep validation piezometers #1									
UltraSeep deployment #1									
UltraSeep validation piezometers #2									
UltraSeep deployment #2									
UltraSeep validation piezometers #3									
UltraSeep deployment #3									
Ship UltraSeep and validation samples									
Demobilize UltraSeep									
Demobilize UltraSeep validation equipment									

The probe was held 1 ft above the sediment surface using the push-pole system. A Y-valve was used to direct the sample water first to a purging syringe, and then to the sampling system. The purging syringe was used to withdraw approximately 60 ml (an estimated three sampler volumes, assuming a 10-m sample tube), and the sample system was then used to fill two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential, and total dissolved solids). The VOA bottles were pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw-cap vials with PTFE-faced silicone septa.

Between stations, the sampling system was flushed with a sequential series of solutions, including (1) surface water, (2) hot RBS solution, and (3) dionized water. Blanks for the surface water survey included equipment rinsate samples, and trip blanks. All samples were unfiltered, and all VOC samples were stored on ice at 4 °C prior to shipment and analysis.

All samples were also individually identified by technology, study, nature, date of collection, and station number. Individual sample identifications were included on the custody sheet that accompanies the sample shipment to the laboratory. Holding time for the VOC samples did not exceed 14 days. Surface water sampling was timed to occur during the falling tide, when discharge conditions are most favorable. The sampling schedule for the surface water survey is shown in Table 3-2 (NSA Panama City) and Table 3-4 (NTC Orlando). All sampling operations were carefully noted in the field log.

Validation samples. Validation groundwater samples for VOC analysis were collected using stainless-steel drive-point piezometers 1/2-inch inside diameter Teflon® tubing to an in-line VOA bottle filler (Solinst, Inc.) powered by a low-flow peristaltic pumping system. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) were pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994. Each piezometer was driven to 2 ft (Trident probe validation) or 1 ft (UltraSeep validation) below the sediment surface using a slide hammer or rotary hammer system.

The piezometer was developed using the low-flow pump and the piezometer was allowed to re-equilibrate with the groundwater. The sample system was then used to fill two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential, and total dissolved solids). The VOA bottles were pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw-cap vials with PTFE-faced silicone septa.

Between stations, the sampling system was flushed with a sequential series of solutions, including (1) surface seawater, (2) hot RBS® solution, and (3) dionized water. Blanks for the validation survey included equipment rinsate samples and trip blanks. All samples were unfiltered. Care was taken during the pumping process to minimize the amount of suspended solids in the samples. All VOC samples were stored on ice at 4 °C prior to shipment and analysis.

All samples were also individually identified by technology, study, nature, date of collection, and station number. Individual sample identifications were included on the custody sheet that accompanies the sample shipment to the laboratory. Holding time for the VOC samples did not exceed 14 days. Validation sampling was timed to occur during the falling tide when discharge conditions are most favorable. The sampling schedule for the Trident validation survey is shown in Table 3-2 (NSA Panama City) and Table 3-4 (NSA Orlando) and for the UltraSeep in Table 3-3 (NSA Panama City) and 3-5 (NTC Orlando). All sampling operations were carefully noted in the field log.

In some cases, the piezometer push met with refusal due to sediment geological conditions or other obstructions. In these cases, the station was relocated by a distance of approximately 1 to 2 m and the push was repeated. In sediments with relatively high clay content, the piezometer may be unable to draw water samples. In these cases, the station was relocated by a distance of approximately 1 to 2 m and re-installed. This process was repeated up to three times, at which time, if the water sampling was still unsuccessful, the site conditions were noted, and the station was abandoned.

3.5.6.4 Sample Analysis

This section discusses two types of sample analysis, VOC analysis and water quality analysis.

VOC analysis. VOC samples from the Trident probe, UltraSeep, surface water, and validation surveys were all analyzed following U.S. EPA method 8260B at a remote laboratory, or using an on-site mobile laboratory. Details of the method, analytical instrumentation, matrix considerations, concentration units, statistical procedures, and detection limits are all described in U.S. EPA, 1996.

Water quality analysis. Sub-samples of the Trident probe, UltraSeep, surface water, and validation samples were analyzed on-site using a Myron model 6b water quality analyzer. The analyzer detects temperature, conductivity, pH, oxidation reduction potential (ORP), and total dissolved solids (TDS). The cell volumes for the measurement are 1.2 ml (pH/ORP) and 5 ml (temperature/conductivity/TDS). Quoted accuracy and precision levels for the meter are shown in Table 3-6. The meter was calibrated to certified National Institute of Standards and Technology standards prior to each survey.

3.5.6.5 Experimental Controls

Experimental controls for the demonstration included validation sampling using drive-point piezometers. For the Trident probe technology, water samples collected from the Trident sampler were compared to water samples collected at collocated piezometer stations. For the UltraSeep technology, discharge measurements determined by the ultrasonic flow meter were compared to estimated discharge rates calculated from water-level measurements in piezometers installed at the UltraSeep stations. Water samples collected during periods of discharge by the UltraSeep were compared to water samples collected from shallow piezometers deployed adjacent to the UltraSeep.

3.5.6.6 Data Quality Parameters

The QA objective of this field investigation was to collect data of known quality. Internal and external QA processes described in the Quality Assurance Project Plan (QAPP; Appendix C) ensured that the QA objectives were met or, if the objectives were not met, corrective action was implemented as described in Subsection 9.10. The QA processes included the application of (1) appropriate field techniques, (2) appropriate analytical methods, and (3) chemical measurement objectives for precision, accuracy, representativeness, completeness, and comparability (PARCC).

“Data quality” refers to the level of reliability associated with a particular data set. Data quality associated with environmental measurement data depends on (1) the sampling plan rationale, (2) the procedures used to collect the samples, and (3) the analytical methods and instrumentation used to make the measurements. Each component carries potential sources of uncertainty and bias that may affect the overall PARCC of the measurement set. While

uncertainty cannot be eliminated entirely from environmental data, the purpose of this project's QA/quality control (QC) program is to ensure that the data collected are of known and documented quality and are useful for the purposes for which they were collected.

Sampling objectives, data types and uses, data quality needs, and data quality indicators used to generate data to satisfy the DQO process are discussed below.

Precision. Precision is the reproducibility of measurements of the same characteristic, usually under a specific set of conditions. For replicate measurements, precision is expressed as the relative percent difference (RPD) or the relative standard deviation (RSD). For the Trident probe and UltraSeep VOC analysis, precision was assessed on the basis of replicate analysis of samples collected at a subset of stations in the field (minimum of 1 out of each 10 stations). Precision for the Trident probe sensors, including temperature and conductivity, was assessed on the basis of replicate analysis performed under controlled laboratory conditions, and at every station in the field. Sensor replicates consisted of a minimum of three individual measurements at the same station. Precision for the UltraSeep sensors was assessed on the basis of replicate analysis performed under controlled laboratory conditions.

Accuracy. Accuracy is the degree to which a measurement agrees with the true value. Analytical accuracy for the Trident probe and UltraSeep VOC samples was assessed on the basis of MS/MSD samples. MS/MSD samples or blank spike samples are analyzed at a frequency of one for every 20 samples. Accuracy is expressed in terms of percent recovery. For Trident probe and UltraSeep sensors, accuracy was assessed on the basis of laboratory calibrations.

Representativeness. Representativeness is a qualitative expression of the degree to which sample data accurately represent the characteristics of a population, parameter variations at a sampling point, or an environmental condition that the data are intended to represent. Representativeness was maximized by (1) selecting the appropriate number of samples and sampling locations, and (2) using appropriate and established sample collection, handling, and analysis techniques to provide information that reflects actual site conditions.

Completeness. Completeness assesses the amount of valid data obtained from a measurement system compared to the amount of data required to achieve a particular statistical level of confidence. The percent completeness was calculated by the number of samples yielding acceptable data divided by the total number of samples planned to be collected, and multiplied by 100. The data validation process determined whether a particular data point was valid and acceptable, estimated and acceptable, or rejected and unacceptable. Complete results were considered acceptable and usable when they are valid or estimated. Sampling results that were considered rejected and unacceptable were considered incomplete. The objective for the degree of completeness for this project was 90 percent.

Comparability. Comparability is a qualitative parameter that expresses the degree of confidence that one data set may be compared to another. This goal was achieved through the use of (1) standardized techniques to collect and analyze samples, and (2) appropriate units to report analytical results. The comparability of the data was maximized by using standard analytical methods when possible, reporting data in consistent units, reporting data in a tabular format, and by validating the results against commonly accepted methodologies.

Table 3-6. Field schedule for the UltraSeep survey validation sampling.

	Range	Resolution	Accuracy
pH	0 to 14 pH	0.01 pH	0.01 pH
ORP	± 999 mV	± 1 mV	±1 mV
Conductivity	0 to 9999 μ S	0.01 < 100 μ S	± 1% of reading
	10 to 200 μ S	0.1 < 1000 μ S	
	5 autoranges	1.0 > 1000 μ S	
TDS	0 to 9999 ppm	0.01 < 100 ppm	± 1% of reading
	10 to 200 ppt	0.1 < 1000 ppm	
	5 autoranges	1.0 > 1000 ppm	
Resistivity	10 K Ω to 30 M Ω	0.01 < 100 K Ω	± 1% of reading
		0.1 < 1000 K Ω	
		0.01 > 1 M Ω	
Temperature	32 to 160F	0.1F	± 0.1F

3.5.6.7 Calibration Procedures, Quality Control Checks, and Corrective Action

Regularly scheduled preventive maintenance procedures to keep all field and laboratory equipment in good working condition are discussed below.

Field equipment. Detailed information regarding maintenance and servicing of field equipment is available in the instruction manual of the specific instrument to be used (Chadwick et al., 2003b). Field personnel recorded service and maintenance information is in the field logbooks. Specific preventive maintenance procedures followed manufacturer recommendations.

Laboratory equipment. The laboratory followed a maintenance schedule for each instrument used to analyze demonstration samples. All instruments were serviced at scheduled intervals to optimize factory specifications. Routine preventive maintenance and major repairs were documented in a maintenance log.

An inventory of items to be kept ready for use in case of instrument failure was maintained and restocked as needed. The list of spare parts included equipment replacement parts that are subject to frequent failure, have a limited lifetime of optimum performance, or that cannot be obtained in a timely manner.

A description of specific preventive maintenance procedures for laboratory equipment is available in the laboratory's QA plan and in the written Standard Operating Procedures (SOPs) maintained by the laboratory. These documents identify the personnel responsible for major preventive and daily maintenance procedures, the frequency and type of maintenance performed, and maintenance documentation procedures.

Instrument calibration and frequency equipment. Laboratory and field equipment was calibrated in accordance with U.S. EPA guidance or the manufacturer's recommendations. Field equipment refers to articles used in conjunction with the Trident probe and UltraSeep, whereas laboratory equipment refers to articles used in the laboratory for sample analysis. Calibration procedures and frequencies are provided in this section.

Field analytical equipment. Measurement equipment internal to the Trident probe and UltraSeep was calibrated at the beginning of the field effort and at prescribed intervals. The frequency of calibrations was performed based on the recommended manufacturer of the individual components as described in the appropriate manual.

All calibration information was recorded in a field logbook or on field forms. In addition, a label specifying the scheduled date of the next calibration was attached to the field equipment. If this identification is not feasible, then calibration records for the equipment will be readily available for reference.

Laboratory analytical equipment. Laboratory instruments were calibrated using procedures and at frequencies specified in laboratory QC requirements and in accordance with U.S. EPA method 8260B (Appendix B). Instruments were calibrated at the start of each analytical batch. The calibration was also confirmed at regular intervals during an analytical batch.

Calibration standards were obtained by the laboratory from commercial vendors. Stock standards were also used to make intermediate standards from which calibration standards are made. All documentation relating to the receipt, mixing, and use of standards was recorded in the appropriate laboratory logbook. Specific handling and documentation requirements for the use of standards were provided in the selected laboratory's QA manual. All instrument malfunctions required immediate corrective action. All actions taken were documented in logbooks. Corrective actions were taken, as necessary, in accordance with the procedures listed in U.S. EPA, 1996 (Appendix B).

3.5.7 Demobilization

Demobilization for the Trident probe and UltraSeep technologies was relatively straightforward. When the survey was completed, the equipment was cleaned, allowed to dry, packed into the manufacturer-provided shipping cases, and shipped to the point of origin. Validation equipment, including the piezometers installed at the site, were removed, cleaned, and return shipped. The only residual water generated during the demonstration was the purge water from the Trident probe water sampler and the purge water from the validation piezometers. The total volume was <5 L and the contamination levels were generally very low. Arrangements were made with the on-site contractor to dispose of the residuals using their existing protocols for the monitoring wells at the site.

3.5.8 Health and Safety Plan

Health and safety procedures during the demonstration were in accordance with the existing Health and Safety Plan (HASP) for NSA Panama City (Naval Facilities Engineering Command, 2004). Health and safety aspects that were particular to this demonstration that are not detailed in the existing HASP are described in Appendix D.

3.6 SELECTION OF ANALYTICAL/TESTING METHODS

The primary CoC at the NSA Panama City site was 1,1-DCE. The analysis of samples for 1,1-DCE and other target VOCs (see Appendix B) were analyzed using U.S. EPA Standard Method 8260B (U.S. EPA, 1996; Appendix B).

The primary CoC at the NTC Orlando site was PCE. The analysis of samples for PCE and other target VOCs were analyzed using U.S. EPA Standard Method 8260B (U.S. EPA, 1996; Appendix B).

Other testing methods selected for the study included the Trident probe system, the UltraSeep system, and associated validation testing. Methodologies for these components of the study are described in detail in Chadwick et al., 2003b, the equipment manuals, demonstration plans, and Appendix C.

3.7 SELECTION OF ANALYTICAL/TESTING LABORATORY

3.7.1 NSA Panama City

The analytical testing was performed by a certified laboratory using the standard U.S. EPA 8260B methodology. It was planned that two analytical laboratories would be used for the study. During the first phase of the study, an on-site laboratory operated by KB Laboratories would be used to provide rapid on-site analysis of water sample collected using the Trident probe and the associated validation piezometers. This plan would enhance the demonstration process by allowing on-site decision to be made regarding the most likely location of VOC discharge related to groundwater.

For the second phase of the demonstration, samples collected using the UltraSeep system would be shipped to a traditional off-site analytical laboratory. This offsite laboratory was the Navy Public Works Center laboratory in San Diego, California, which had extensive experience analyzing groundwater and surface water using method 8260B. Hurricane warnings during the demonstration precluded the on-site laboratory from traveling to the site. Instead, sample batches were shipped by FedEx® to the KB Laboratories lab for expedited overnight analysis, which included all the Trident probe and UltraSeep samples. A subset of the UltraSeep samples were split and shipped to the Public Works Center lab for confirmatory analysis.

3.7.2 NTC Orlando

The analytical testing was performed by a certified laboratory using the standard U.S. EPA 8260B methodology. All Trident probe samples were analyzed by an on-site laboratory operated by KB Laboratories to provide rapid on-site analysis of water sample collected using the Trident probe and the associated validation piezometers. This on-site analysis enhanced the demonstration process by allowing an on-site decision to be made regarding the most likely location of VOC discharge related to groundwater. For the second phase of the demonstration, samples collected using the UltraSeep system were shipped to a traditional off-site analytical laboratory. This laboratory was also KB Laboratories.

3.7.3 Management and Staffing

3.7.3.1 NSA Panama City

Primary responsibility for execution of the demonstration were taken by Bart Chadwick (SSC San Diego) and Amy Hawkins (NFESC). The primary site representatives were Philip McGinnis and Dan Waddill, Engineering Field Division South (EFD South). Primary

responsibility for regulatory technical review was with Bruce Labelle (Cal/EPA). The QA officer for the project was Joel Guerrero (SSC San Diego). A project management and staffing chart for the NSA Panama City demonstration is provided in Figure 3-24.

3.7.3.2 NTC Orlando

Primary responsibility for execution of the demonstration was taken by Bart Chadwick (SSC San Diego) and Amy Hawkins (NFESC). The primary site representative was Mike Singletary (EFD South). Primary responsibility for regulatory technical review was with Bruce Labelle (Cal/EPA). The QA officer for the project was Joel Guerrero (SSC San Diego). A project management and staffing chart for the NTC Orlando demonstration is provided in Figure 3-25.

3.7.4 Demonstration Schedule

Table 3-7 shows the schedule for NSA Panama City, including the date and duration of each phase of the demonstration. Table 3-8 shows the schedule for NTC Orlando, including the date and duration of each phase of the demonstration.

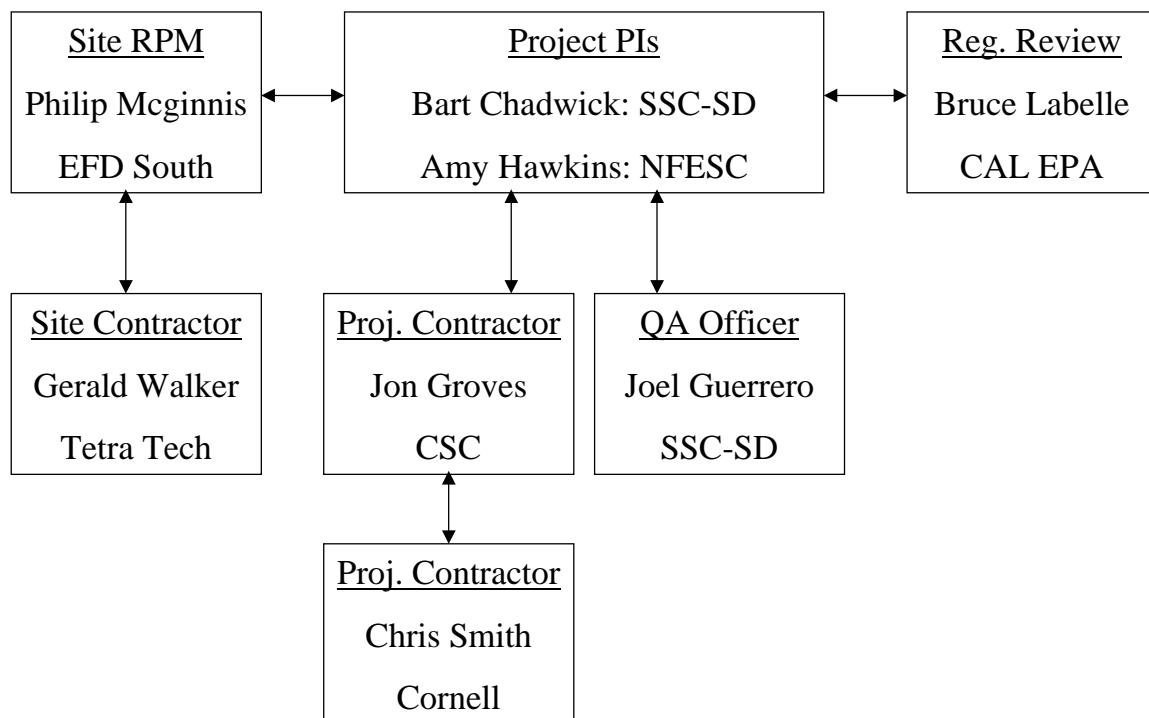


Figure 3-24. Project management and staffing for NSA Panama City demonstration.

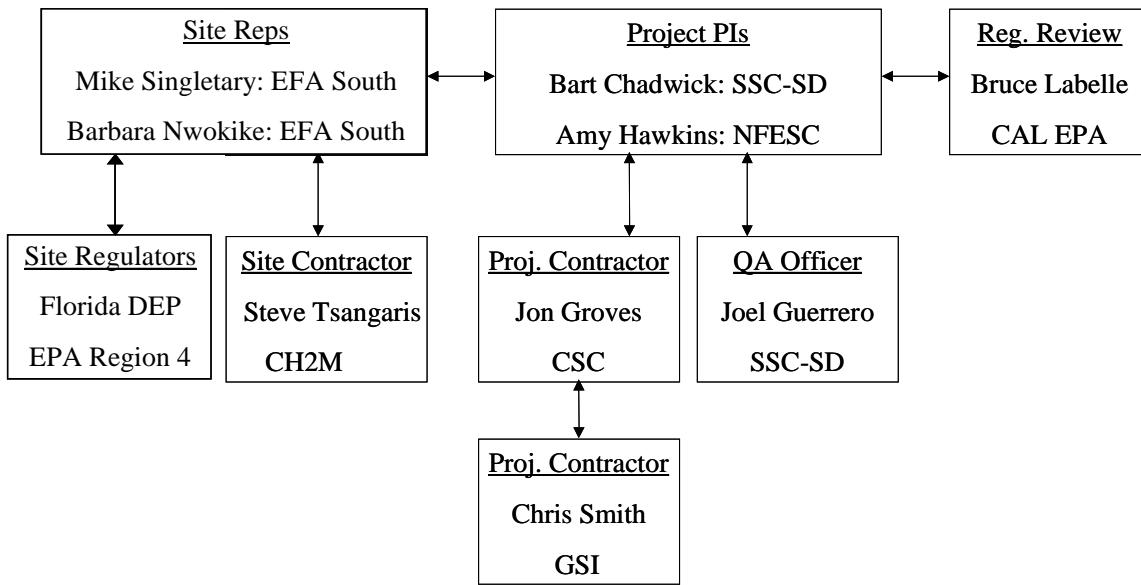


Figure 3-25. Project management and staffing for NTC Orlando demonstration.

Table 3-7. NSA Panama City demonstration schedule.

Demonstration Phase	Week of CY04												
	26-Jul	2-Aug	9-Aug	16-Aug	23-Aug	30-Aug	6-Sep	13-Sep	20-Sep	27-Sep	4-Oct	11-Oct	
Mobilization													
Ship Equipment to Site													
Trident Field Program													
Trident On-site Sample Analysis													
UltraSeep Station Selection													
UltraSeep Field Program													
Demobilization													
Return shippment													
Laboratory Sample Analysis													
Data analysis													→ 6-Dec
Draft Report													→ 3-Jan-05

Table 3-8. NTC Orlando demonstration schedule.

Demonstration Phase	Week of CY05												
	13-Jun	20-Jun	27-Jun	4-Jul	11-Jul	18-Jul	25-Jul	1-Aug	8-Aug	15-Aug	22-Aug	29-Aug	
Mobilization													
Ship Equipment to Site													
Trident Field Program													
Trident On-site Sample Analysis													
UltraSeep Station Selection													
UltraSEep Field Program													
Demobilization													
Return shippment													
Laboratory Sample Analysis													
Data analysis													→ 03/2006
Draft Report													→ 06/2006

4. PERFORMANCE ASSESSMENT

4.1 PERFORMANCE CRITERIA

Performance criteria for the Trident probe and UltraSeep technologies were based on the performance objectives described in Section 3. The performance criteria are described below and summarized in Tables 4-1 and 4-2 for the Trident probe and UltraSeep technologies, respectively.

4.1.1 Trident Probe Performance Criteria

4.1.1.1 Mobilize, Operate, and Demobilize Equipment

This performance objective requires demonstration that the Trident probe system can be efficiently prepared, shipped, assembled, operated, broken down, and return shipped. The qualitative criteria for this objective include successful pre-demonstration cleaning and calibration, as well as successful shipment to and from the site in good working condition (Table 4-1).

4.1.1.2 Obtain Field Measurements within Specified Measurement Quality Objectives

This performance objective requires demonstration that the Trident probe sensors can obtain field measurements of conductivity and temperature within specified requirements of accuracy and precision. The quantitative criteria for this objective include accuracy, precision, and completeness thresholds specified in the measurement quality objectives of the QAPP and shown in Table 4-2.

4.1.1.3 Obtain Field and Equipment Blanks Free of Contamination

This performance objective requires that the Trident probe water-sampling probe can be demonstrated to collect blank samples that are free from contamination for the target CoCs. The quantitative criteria for this objective specify that the concentration of VOCs in rinsate and trip blanks must be non-detect or not statistically different from the blank source water (Table 4-2).

4.1.1.4 Collect Valid Water Samples of Sufficient Volume to Characterize CoC Distributions

This performance objective requires that water samples collected by the Trident probe be representative of sub-surface groundwater conditions at the point of collection, and that a sufficient volume of water be acquired to perform the required analyses. The quantitative criteria for validity will be based on comparison to validation samples collected using a piezometer system installed at a subset of the Trident probe stations. The quantitative criteria for sufficient volume will require a minimum of 80 ml for VOC analysis and 40 ml for water quality analysis (120 ml) of sub-surface water be collected (Table 4-2).

4.1.1.5 Produce Spatial Maps of Groundwater Tracers at the Sites of Interest

This performance objective requires that data of sufficient quantity, quality, and completeness be collected to produce spatial maps of sub-surface temperature, conductivity, and 1,1-DCE concentrations. The quantitative criteria for this objective specify that completeness for the conductivity and temperature sensors meet or exceed 90% of the total number of stations where a successful direct-push is made, and that the completeness for the water

sampling probe meet or exceed 90% of the total number of stations where grain size characteristics permit the collection of water (Table 4-2).

4.1.1.6 Identify the Presence or Absence and Areas of Potential Groundwater CoC Discharge to Surface Water

This performance objective requires that areas of likely groundwater discharge be identified on the basis of the sub-surface temperature, conductivity and/or VOC distributional maps. The qualitative criteria for this objective include assessment of temperature, conductivity, and VOC distributions to identify spatial regions or individual stations where conditions depart from ambient conditions in a manner consistent with the influence of groundwater discharge (Table 4-2).

4.1.2 UltraSeep Performance Criteria

4.1.2.1 Mobilize, Operate, and Demobilize Equipment

This performance objective requires demonstration that the UltraSeep system can be efficiently prepared, shipped, assembled, operated, broken down, and return shipped. The qualitative criteria for this objective include successful pre-demonstration cleaning and calibration, as well as successful shipment to and from the site in good working condition (Table 4-2).

4.1.2.2 Obtain Field Measurements within Specified Measurement Quality Objectives

This performance objective requires that the UltraSeep sensors can be demonstrated to obtain field measurements of flow, conductivity, and temperature within specified requirements of accuracy and precision. The quantitative criteria for this objective include accuracy, precision, and completeness thresholds as specified in the measurement quality objectives of the QAPP and shown in Table 4-2.

4.1.2.3 Obtain Field and Equipment Blanks Free of Contamination

This performance objective requires that the UltraSeep water sampling system can be demonstrated to collect blank samples that are free from contamination for the target CoCs. The quantitative criteria for this objective specify that the concentration of VOCs in rinsate and trip blanks must be non-detect or not statistically different from the blank source water (Table 4-2).

4.1.2.4 Obtain Valid, Continuous Seepage Flow Records over Required Time Periods

This performance objective requires that the UltraSeep flow system be demonstrated to record continuous flow measurements over the required time period for a deployment. The quantitative criteria for this objective specify that the system must collect flow data continuously for the 25-hour deployment period, and that completeness for the flow sensor meet or exceed 90% of the total deployment duration. The qualitative criteria for this objective specify that the magnitude and direction of the flow be qualitatively representative of the flow estimated from the hydraulic gradient measured in piezometers installed adjacent to the UltraSeep (Table 4-2).

4.1.2.5 Obtain Valid Discharge Water Samples of Sufficient Volume to Characterize CoC Concentrations during Periods of Positive Seepage

This performance objective requires that the UltraSeep water sampling system be demonstrated to collect representative discharge water samples during periods of positive seepage.

The quantitative criteria for representativeness will be based on comparison of seepage water samples to 1-ft sub-surface piezometer samples collected during discharge periods. The quantitative criteria for sample volume specify that a minimum of 120 ml (80 ml for VOCs and 40 ml for water quality) of discharge water be collected using the UltraSeep water sampler, subject to the provision that sufficient discharge is present during the sampling period to produce the minimum sample volume (Table 4-2).

4.1.3 Factors Affecting Technology Performance

4.1.3.1 Trident Probe

The Trident probe has undergone a series of laboratory and initial field tests, providing confidence that the system will perform well during the demonstration phase (Chadwick et al., 2002a). The following potential limitations anticipated for the Trident probe are based on experience from the initial testing phase:

- Potential inability to direct-push the probe to the desired sub-surface depth
- Potential inability to collect water in fine-grained sediments
- Potential absence of a temperature or conductivity contrast in the impinging groundwater
- Potential confounding presence of a temperature or conductivity contrast not associated with groundwater discharge
- Potential breakage of the probes on rocks or debris

The demonstration site at NSA Panama City was chosen while considering these potential limitations. The sediments were generally of a sandy nature, which minimized any problems associated with direct-push methods or clogging of the water sampler. The average salinity in St. Andrews Bay is about 31, while the salinity of groundwater measured in shoreline wells is near 0, indicating that conductivity contrast would be efficient enough to identify groundwater discharge areas. A site inspection indicated little in the way of rock or debris that would impede direct-push operations for the Trident probe.

Similarly, the NTC Orlando demonstration site was also chosen while considering these potential limitations. The sediments were generally of a sandy nature, which minimized any problems associated with direct-push methods or clogging the water sampler. Historical data indicated that the average temperature difference between Lake Druid and the groundwater in shoreline wells is about 5 °C, which indicates temperature contrast would be efficient enough to identify groundwater discharge areas. A site inspection of boring logs indicated little in the way of rock or debris that would impede Trident probe direct-push operations.

4.1.3.2 UltraSeep

The initial UltraSeep tests were successful and provided confidence for success during the ESTCP demonstration phase. The primary anticipated technical risks included the following:

- Limited chemical detection due to dilution in the seepage funnel
- Inability to collect water samples due to low discharge rates
- Interference of the flow measurements due to gas discharge from the sediments
- Logistical problems associated with site access and leaving equipment deployed on-site for a few days

Table 4-1. Matrix spike, matrix spike duplicate, and field duplicate results for the Trident probe VOC samples.

Panama City - Trident Matrix Spike/Matrix Spike Duplicates												
Compound	8/12/2004			8/12/2004			8/13/2004			Control Limits		
	MS	MSD	RPD	MS	MSD	RPD	MS	MSD	RPD	Lower	Upper	RPD
PCE	97	97	0	97	97	1	84	97	14	73	131	20
TCE	96	93	3	94	102	8	89	96	7	64	127	20
1,1-DCE	95	86	9	94	100	7	82	94	14	51	143	20
Compound	8/14/2004			8/17/2004			N/A			Control Limits		
	MS	MSD	RPD	MS	MSD	RPD	MS	MSD	RPD	Lower	Upper	RPD
PCE	119	96	21	98	99	2	-	-	-	73	131	20
TCE	132	97	30	102	100	2	-	-	-	64	127	20
1,1-DCE	126	90	33	98	91	8	-	-	-	51	143	20
Panama City - Trident Field Duplicates												
Compound	TD-T2-4-SS-A/B			TD-T4-2-SS-A/B			TD-T5-6-SS-A/B			Control Limits		
	1	2	RPD	1	2	RPD	1	2	RPD	RPD		
PCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
TCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
1,1-DCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
Compound	TD-T2-4-S-A/B			TD-T4-2-S-A/B			TD-T5-6-S-A/B			Control Limits		
	1	2	RPD	1	2	RPD	1	2	RPD	RPD		
PCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
TCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
1,1-DCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
Orlando - Trident Matrix Spike/Matrix Spike Duplicates												
Compound	6/30/2005			7/3/2005			7/3/2005			Control Limits		
	MS	MSD	RPD	MS	MSD	RPD	MS	MSD	RPD	Lower	Upper	RPD
PCE	98	90	8	103	108	5	113	104	9	56	138	20
TCE	103	98	5	104	111	7	110	107	3	50	147	20
cis-DCE	113	115	2	113	116	3	120	123	3	59	149	20
trans-DCE	109	105	4	112	116	3	119	121	2	41	157	20
VC	103	94	9	101	104	4	105	104	1	20	187	20
Compound	7/5/2005			7/6/2005			N/A			Control Limits		
	MS	MSD	RPD	MS	MSD	RPD	MS	MSD	RPD	Lower	Upper	RPD
PCE	106	106	0	101	104	3	-	-	-	56	138	20
TCE	113	116	2	116	110	5	-	-	-	50	147	20
cis-DCE	123	129	5	121	116	5	-	-	-	59	149	20
trans-DCE	130	133	3	122	118	3	-	-	-	41	157	20
VC	111	110	1	89	103	14	-	-	-	20	187	20
Orlando - Trident Field Duplicates												
Compound	TD-T3-3-PW			TD-T4-3-PW			TD-T5-1-PW			Control Limits		
	1	2	RPD	1	2	RPD	1	2	RPD	RPD		
PCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
TCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
cis-DCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
trans-DCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
VC	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
Compound	TD-T3-3-SW			TD-T4-3-SW			TD-T5-1-SW			Control Limits		
	1	2	RPD	1	2	RPD	1	2	RPD	RPD		
PCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
TCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
cis-DCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
trans-DCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		
VC	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30		

Table 4-2. Trident probe performance summary.

Type	Criteria	Expected	Actual - Panama City	Actual - Orlando
Qualitative	Mobilize, operate, and demobilization the equipment	As specified in the Demo Plan.		
	• Pre-calibrate sensors	Within spec.	✓ Calibrated within spec prior to shipment	✓ Calibrated within spec prior to shipment
	• Pre-clean sampler	Based on CoC	✓ Pre-cleaned for VOCs	✓ Pre-cleaned for VOCs
	• Ship to site	Arrive in working order	✓ Arrived in working order	✓ Arrived in working order
Quantitative	Rapidly position, deploy, operate, and reposition the equipment	As specified in the Demo Plan.		
	• Cond/Temp/Position	<30 min/station sensor only	NA - sensor recorded during water sampling	Average 13 min/station
	• Including porewater	<60 min/station including water	Average 50 min/station (32 min/station best day)	Average 56 min/station (including storm delays)
Quantitative	Push probe to required/design depth	Target: 60 cm	35 of 35 stations met target	37 of 37 stations met target

Table 4-2. Trident probe performance summary. (continued)

Type	Criteria	Expected	Actual - Panama City	Actual - Orlando
Quantitative	Obtain field measurements within specified measurement quality objectives	As specified in the MQOs in the QAPP.		
	• Conductivity	Accuracy: $\leq 2\%$ FS Precision: ≤ 2 mS/cm	Probe Acc: 0.1 - 1.6 % Ref Acc: 0.0 - 1.0 % Probe Prec: 0.0 - 0.21 mS/cm Ref Prec: 0.0 - 0.12 mS/cm	Probe Acc: 0.1 - 0.8 % Ref Acc: 0.1 - 1.3 % Probe Prec: 0.0 - 0.42 mS/cm Ref Prec: 0.0 - 0.03 mS/cm
	• Temperature	Accuracy: ≤ 0.1 C Precision: ≤ 0.05 C	Probe Acc: 0.0 - 0.01 C Ref Acc: 0.0 - 0.01 C Probe Prec: 0.01 - 0.04 C Ref Prec: 0.03 - 0.05 C	Probe Acc: 0.0 - 0.05 C Ref Acc: 0.0 - 0.01 C Probe Prec: 0.01 - 0.03 C Ref Prec: 0.0 - 0.01 C
	• VOCs - detection limit	PQL: 1-5 ug/L	PQL: 1-5 ug/L	PQL: 1-20 ug/L Increased PQL due to high DCE concentrations required dilution for 2 Trident samples and 1 piezometer sample
	- analytical performance	Surrogate Spike Recovery w/i limits	717 of 724 analyses w/i control limits 4>UCL, 3<LCL	540 of 541 analyses w/i control limits 1<LCL (Lab blank)
	- bias	Matrix spike recovery w/i limits Lab control spike recovery w/i limits	29 of 30 analyses w/i control limits ¹ 1>UCL 24 of 24 analyses w/i control limits ¹	50 of 50 analyses w/i control limits ² 39 of 40 analyses w/i control limits ² 1>UCL
	- precision	MSDs w/i limits Field Dups w/i limits	12 of 15 analyses w/i control limits ¹ 3>RPDL (all in one sample) 18 of 18 analyses w/i control limits ¹	25 of 25 analyses w/i control limits ² 30 of 30 analyses w/i control limits ²

¹For target analytes PCE, TCE, and 1,1-DCE

²For target analytes PCE, TCE, cis-DCE, trans-DCE, and VC

Table 4-2. Trident probe performance summary. (continued)

Type	Criteria	Expected	Actual - Panama City	Actual - Orlando
Quantitative	Collect valid water samples of sufficient volume to characterize CoC distributions	As specified in the MQOs in the QAPP.		
	• VOCs by 8260B	Volume: >80 ml for every station Validation: comparable to shallow piezometer samples	35 of 35 stations sufficient volume Trident and piezometer samples in agreement - ND for all target analytes at all validation stations	36 of 37 stations sufficient volume no sample at 1 station (T3-1) due to high fines content Trident and piezometer samples in agreement - probabilities for 2-sided test using 1/2 PQL All Stations: no difference P=0.28 Station T3-6: no difference P=0.57 Station T3-7: no difference P=0.31 cis-DCE: no difference P=0.35 TCE: no difference P=0.18
	• Water quality by UltraMeter	Volume: >40 ml for every station	35 of 35 stations sufficient volume	36 of 37 stations sufficient volume no sample at 1 station (T3-1) due to high fines content

¹For target analytes PCE, TCE, and 1,1-DCE

²For target analytes PCE, TCE, cis-DCE, trans-DCE, and VC

Table 4.2. Trident probe performance summary. (continued)

Type	Criteria	Expected	Actual - Panama City	Actual - Orlando
Quantitative	Obtain trip and equipment blanks that are free of contamination	As specified in the MQOs in the QAPP.		
	<ul style="list-style-type: none"> • Equipment rinsate • Trip blank 	<ul style="list-style-type: none"> ND or comparable to rinse water ND or comparable to pre-trip 	<ul style="list-style-type: none"> 15 of 15 analyses ND¹ 15 of 15 analyses ND¹ 	<ul style="list-style-type: none"> 30 of 30 analyses ND² NA - analyzed on site
Qualitative	Produce spatial maps of groundwater tracers at the sites of interest	Based on MQOs for completeness as specified in the QAPP	Successfully produced spatial maps for discharge indicators and VOCs	Successfully produced spatial maps for discharge indicators and VOCs
	<ul style="list-style-type: none"> • Conductivity • Temperature • VOCs 	<ul style="list-style-type: none"> Completeness > 95% Completeness > 95% Completeness > 95% 	<ul style="list-style-type: none"> Cond. Completeness: 100% Temp Completeness: 100% VOC Completeness: 100% 	<ul style="list-style-type: none"> Cond. Completeness: NA (fresh) Temp Completeness: 100% VOC Completeness: 97%
Qualitative	Identify the presence or absence and areas of potential groundwater CoC discharge to surface water	If present, isolate discharge areas based on temperature and/or conductivity contrast and/or presence of CoCs	Isolated potential discharge zones primarily based on conductivity contrast. CoCs were attenuated below level of detection.	Isolated potential discharge zones primarily based on temperature. CoC distribution corresponded closely to identified discharge zones.

¹For target analytes PCE, TCE, and 1,1-DCE

²For target analytes PCE, TCE, cis-DCE, trans-DCE, and VC

The UltraSeep water sampler draws samples from the volume of water enclosed by the seepage funnel. The installed funnel has an average height of 2.67 cm, and a volume of 5236 cm³. When the UltraSeep is installed, the water enclosed by the funnel is surface water. As discharge occurs, the funnel begins to fill with discharge water (groundwater). Thus, at least initially, the water sampling system may be sampling a mixture of surface water and discharge water. This dilution effect can be corrected for based on the measured flow rate and measured surface water concentration. However, the dilution may limit the detectability of the CoC. For example, if the CoC has a DL of 1 µg/L, but the discharge water is diluted by a factor of 10 with surface water at 0 µg/L, then the detection of the UltraSeep will be limited to 10 µg/L. The extent to which this impacted the demonstration depended on the discharge rates and concentrations present at the site.

Because the UltraSeep water sampling system is triggered by the flow meter response level, it is possible that in areas of very low discharge, or recharge (negative seepage), the system would not collect water samples. This outcome was not be interpreted as a failure of the system, but rather as a characteristic of the site. If there is little or no discharge from the site, then it is consistent that no discharge sample would be collected.

In some of the test deployments it was found that the flow meter could become filled with gas that was naturally released from the sediments during the deployment. If the flow meter fills with gas, this can impede the flow, and confound the ultrasonic detection system. To anticipate this problem, a baffle has been installed over the flow meter intake from the funnel to defeat gas from entering the flow meter. In addition, a gas trap and purge system has been installed at the high point of the funnel. These improvements, combined with the sandy character of the sediments should minimize any problems associated with gas discharge.

We did not encounter any major logistical or equipment security issues at the NSA Panama City or NTC Orlando sites. The sampling schedule at NSA Panama City was somewhat altered due to hurricane warnings during the demonstration period.

4.2 PERFORMANCE CONFIRMATION METHODS

Performance confirmation during the mobilization phase was assessed based on achieving the performance criteria described in Section 4.1. Performance results are summarized in Tables 4-2 and 4-3. For each objective, confirmation was achieved by meeting the stated criteria for the objective.

4.2.1 Trident Probe Performance Confirmation

The methods of confirmation for determining whether the performance criteria were met are described for each objective in Subsections 4.2.1.2 through 4.2.1.6.

4.2.1.1 Mobilize, Operate, and Demobilize Equipment

The qualitative criteria for this objective included successful pre-demonstration cleaning and calibration, as well as successful shipment to and from the site in good working condition (Table 4-2). Confirmation of these criteria was determined by the Principal Investigator (PI) through a process of observation, testing, inspection and documentation. The PI observed the equipment decontamination process, inspected the equipment at the end of the process, and documented the effectiveness of the process in the logbook. The PI observed the sensor testing and calibration procedures and documented the results and effectiveness of these procedures in the logbook. The PI oversaw the packaging and shipment process, and

documented the functionality and condition of the equipment upon arrival at the demonstration site.

4.2.1.2 Obtain Field Measurements within Specified Measurement Quality Objectives

The quantitative criteria for this objective included accuracy, precision, and completeness thresholds as specified in the measurement quality objectives of the QAPP, and shown in Table 4-2. Confirmation of these criteria was determined by the PI through a process of calibration, testing, analysis, and documentation.

Performance confirmation for the temperature sensor was achieved under controlled laboratory conditions by immersing the sensor in a temperature-regulated water solution, allowing the sensor responses to stabilize, and recording a minimum of three readings from the Trident probe temperature sensor and the high-accuracy digital oceanographic thermometer used as the calibration standard (Appendix A). The accuracy of the Trident probe temperature was then assessed by comparing the residuals of the calibrated Trident probe sensor to the accuracy criteria specified in the measurement quality objectives (MQOs) of the QAPP. The precision of the sensor was calculated as the standard deviation of the replicate readings, and then compared to the precision criteria specified in the MQOs of the QAPP. If the sensor was within these criteria, the results are documented in the logbook. If the sensor was outside these criteria, it is recalibrated and the process ass repeated. If the sensor met the performance criteria as described above, the field measurements were accepted as meeting the performance objectives.

Performance confirmation for the conductivity sensor was achieved under controlled laboratory conditions by immersing the sensor in a NIST-certified conductivity solution, allowing the sensor response to stabilize, and recording a minimum of three readings from the Trident probe and reference sensors (Appendix A). The accuracy of the Trident probe conductivity was then assessed by comparing the recorded values to the conductivity of the calibration standard. The resulting difference should be less than the specified accuracy of the sensor. The precision of the sensor was calculated as the standard deviation of the replicate readings, and then compared to the precision criteria specified in the MQOs of the QAPP. If the sensor was within these criteria, the results are documented in the logbook. If the sensor was outside these criteria, it is recalibrated and the process repeated. If the sensor met the performance criteria as described above, the field measurements were accepted as meeting the performance objectives.

Performance confirmation for the Trident probe VOC samples was achieved through laboratory and field control samples, including surrogate spike samples, matrix spike and matrix spike duplicates, laboratory control samples, and field duplicates. Surrogate spikes reflect analytical performance, whereas matrix spikes and laboratory control spikes provide measures of accuracy, and matrix spike duplicates and field duplicates provide measures of precision. Performance for these parameters was quantified by comparison to criteria specified in the MQOs of the QAPP. Results for MS/MSDs and field duplicates are summarized in Table 4-1. Overall performance is shown in Table 4-2. Details of other performance measures are included in the detailed laboratory results in Appendix B.

4.2.1.3 Obtain Field and Equipment Blanks Free of Contamination

The quantitative criteria for this objective specify that the concentration of VOCs in rinsate and trip blanks must be non-detect, or not statistically different from the blank source water (Table 4-2).

The PI determined confirmation of these criteria through a process of testing, analysis, review, and documentation. Blank samples were collected and analyzed in accordance with procedures described in the QAPP. The PI reviewed results from the analysis of the blanks to determine if any of the CoCs were present at levels exceeding the detection limit of the analytical method.

If levels were below detection, the field equipment and handling processes were accepted as successful. If any of the CoC analytes exceed detection levels, replicate results from the rinsate and/or field blanks were compared to replicate analyses of the blank source water. If the blanks and blank source water concentrations were not different, the field equipment and handling processes were accepted as successful. If contamination was detected in the blank that exceeds these criteria, the cleaning and handling procedures were reviewed, corrective action was taken as required, and the samples collected using the system could be qualified.

4.2.1.4 Collect Valid Water Samples of Sufficient Volume of Characterize CoC Distributions

The quantitative criteria for validity was based on comparison to validation samples collected using a piezometer system installed at a subset of the Trident probe stations. The quantitative criteria for sufficient volume will require a minimum of 120 ml (80 ml for VOC and 40 ml for water quality) of sub-surface water be collected (Table 4-2). The PI determined confirmation of these criteria through a process of measurement, analysis, review, and documentation. Validation measurements for comparison with the Trident probe water sample results were developed using piezometers installed at a subset of the Trident probe stations. Water samples were collected synoptically from the Trident probe and the adjacent piezometer. VOC concentrations and water quality characteristics were compared statistically to assess the general level of agreement or disagreement between the Trident probe samples and the validation samples collected with the piezometer.

4.2.1.5 Produce Spatial Maps of Groundwater Tracers at Sites of Interest

The quantitative criteria for this objective specify that completeness for the conductivity and temperature sensors meet or exceed 90% of the total number of stations where a successful direct-push is made, and that the completeness for the water sampling probe meet or exceed 90% of the total number of stations where grain size characteristics permit the collection of water (Table 4-2). Confirmation of these criteria was determined by the PI through a process of testing, analysis, review and documentation. Test results during the field demonstration were recorded and analyzed for completeness. Completeness was calculated as

$$\% C = (V/T) \times 100\%,$$

where

$\% C$ = Percent completeness

V = Number of measurements judged valid

T = Total number of measurements

4.2.1.6 Identify Presence or Absence and Areas of Potential Groundwater CoC Discharge to Surface Water

This performance objective requires that areas of likely groundwater discharge be identified on the basis of the sub-surface temperature, conductivity, and/or VOC distributional maps. The qualitative criteria for this objective include assessment of temperature, conductivity, and VOC distributions to identify spatial regions or individual stations where conditions depart from ambient conditions in a manner consistent with the influence of groundwater discharge (Table 4-2). The PI determined confirmation of these criteria through a process of analysis, review, best professional judgment, and documentation. Analysis for the confirmation included assessment of the offshore spatial patterns in relation to the existing baseline data for the shoreline monitoring wells and DPT stations, and assessment of the validation samples collected with the piezometers.

The expectation is that if significant discharge of CoCs is occurring via groundwater, the locations of discharge would be characterized by contrast in conductivity (NSA Panama City–low), temperature (NSA Panama City/NTC Orlando–low), 1,1-DCE and/or breakdown products (NSA Panama City–high), and PCE and breakdown products (NTC Orlando–high) relative to ambient conditions, and that these conditions would be substantiated by the validation sampling. The PI judged the confirmation a success if (1) areas of discharge were identified with the Trident probe and confirmed by the validation, or (2) no areas of discharge were identified with the Trident probe and this finding is supported by the validation.

4.2.2 UltraSeep Performance Confirmation

4.2.2.1 Mobilize, Operate, and Demobilize Equipment

The qualitative criteria for this objective include successful pre-demonstration cleaning and calibration, as well as successful shipment to and from the site in good working condition (Table 4-4). Confirmation of these criteria was determined by the PI through a process of observation, testing, inspection, and documentation. The equipment decontamination process was observed, equipment at the end of the process was inspected, and process effectiveness was documented in the logbook. The sensor testing and calibration procedures were observed by the PI and the results and effectiveness of these procedures were documented in the logbook. The PI also oversaw the packaging and shipment process, and documented equipment functionality and condition upon arrival at the demonstration site.

4.2.2.2 Obtain Field Measurements within Specified Measurement Quality Objectives

The quantitative criteria for this objective include accuracy, precision, and completeness thresholds as specified in the measurement quality objectives of the QAPP, and shown in Table 4-3. Confirmation of these criteria was determined by the PI through a process of calibration, testing, analysis and documentation. Performance confirmation for the temperature sensor was achieved under controlled laboratory conditions by immersing the sensor in a temperature-regulated water solution, allowing the sensor responses to stabilize, and recording a minimum of three readings from the Trident probe temperature sensor and the high-accuracy, digital oceanographic thermometer used as the calibration standard (Appendix A). The accuracy of the UltraSeep temperature was then assessed by comparing the mean of the recorded values to the calibration thermometer. The precision of the sensor was calculated as the standard deviation of the replicate readings, and then compared to the precision criteria specified in the MQOs of the QAPP. If the sensor was within these criteria,

the results were documented in the logbook. If the sensor was outside criteria, it is recalibrated and the process repeated. If the sensor met the performance criteria described above, the field measurements were accepted as meeting the performance objectives.

Performance confirmation for the conductivity sensor was achieved under controlled laboratory conditions by immersing the sensor in a NIST-certified conductivity solution, which allowed the sensor response to stabilize and record a minimum of three sensor readings (Appendix A). The accuracy of the UltraSeep conductivity was then assessed by comparing the recorded values to the conductivity of the calibration standard. The resulting difference should be less than the specified accuracy of the sensor. The precision of the sensor was calculated as the standard deviation of the 10 readings, and then compared to the precision criteria specified in the MQOs of the QAPP. If the sensor was within these criteria, the results were documented in the logbook. If the sensor was outside these criteria, it was recalibrated and the process repeated. If the sensor met the performance criteria as described above, the field measurements were accepted as meeting the performance objectives.

Performance confirmation for the flow sensor was achieved under controlled laboratory conditions by metering a series of known flow rates under constant head through the flow tube, which allowed the sensor response to stabilize and record a minimum of three sensor readings (Appendix A). The accuracy of the UltraSeep flow sensor was then assessed by comparing the mean of the recorded values to the measured value determined by capturing the flow water in a graduated cylinder for a specified time. The resulting difference should be less than the specified accuracy of the sensor. The precision of the sensor was calculated as the standard deviation of the replicate readings, and then compared to the precision criteria specified in the MQOs of the QAPP. If the sensor was within these criteria, the results were documented in the logbook. If the sensor was outside these criteria, the sensor was recalibrated and the process repeated. If the sensor met the performance criteria as described above, the field measurements were accepted as meeting the performance objectives.

Performance confirmation for the UltraSeep VOC samples was achieved through laboratory and field control samples, including surrogate spike samples, MS/MSDs, laboratory control samples, and field duplicates. Surrogate spikes reflect analytical performance, while matrix spikes and laboratory control spikes provide measures of accuracy, and matrix spike duplicates and field duplicates provide measures of precision. Performance for these parameters was quantified by comparison to criteria specified in the MQOs of the QAPP. Results for MS/MSDs and field duplicates are summarized in Table 4-3. Overall performance is shown in Table 4-4. Details of other performance measures are included in the detailed laboratory results in Appendix B.

4.2.2.3 Obtain Field and Equipment Blanks Free of Contamination

The quantitative criteria for this objective specify that the concentration of VOCs in rinsate and trip blanks must be non-detect, or not statistically different from the blank source water (Table 4-4). The PI determined confirmation of these criteria through a process of testing, analysis, review, and documentation. Blank samples were collected and analyzed in accordance with procedures described in the QAPP. Results from the analysis of the blanks were reviewed by the PI to determine if any of the CoCs are present at levels exceeding the detection limit of the analytical method. If levels are below detection, the field equipment and handling processes were accepted as successful. If any of the CoC analytes exceed detection levels, replicate results from the rinsate and/or field blanks were compared to replicate analyses of the blank source water. If the blanks and blank source water concentrations were

not different, the field equipment and handling processes were accepted as successful. If contamination was detected in the blank that exceeds these criteria, the cleaning and handling procedures were reviewed, corrective action taken as required, and the samples collected using the system were qualified.

4.2.2.4 Obtain Valid, Continuous Seepage Flow Records over Required Time Periods

The quantitative criteria for this objective specify that the system must collect flow data continuously for the 24 or 25-hour deployment period, and that completeness for the flow sensor meet or exceed 90% of the total deployment duration. The qualitative criteria for this objective specify that the magnitude and direction of the flow be qualitatively representative of the flow estimated from the hydraulic gradient measured in piezometers installed adjacent to the UltraSeep (Table 4-4). The PI determined confirmation of these criteria through a process of measurement, analysis, review, and documentation. Calculated flow rates based on water level and hydraulic conductivity measurements in the piezometers were compared to the direct flow measurements from the UltraSeep.

4.2.2.5 Obtain Valid Discharge Water Samples of Sufficient Volume to Characterize CoC Concentrations during Periods of Positive Seepage

The qualitative criteria for validity were based on comparison of seepage water samples to 1-ft sub-surface piezometer samples collected during discharge periods. The quantitative criteria for sample volume specify that a minimum of 120 ml of discharge water be collected using the UltraSeep water sampler, subject to the provision that sufficient discharge is present during the sampling period to produce the minimum sample volume (Table 4-4).

The PI determined confirmation of these criteria through a process of measurement, analysis, review, and documentation. Validation measurements for comparison with the UltraSeep flow and water sample results were developed using piezometers installed adjacent to each of the three UltraSeep stations. VOC concentrations and water quality characteristics were compared qualitatively to assess the general level of agreement or disagreement between the UltraSeep discharge samples and the validation samples collected with the piezometer.

Table 4-3. MS/MSD and field duplicate results for UltraSeep VOC samples.

Panama City - UltraSeep Matrix Spike/Matrix Spike Duplicates													
Compound	8/17/2004			8/21/2004			N/A			Control Limits			
	MS	MSD	RPD	MS	MSD	RPD	MS	MSD	RPD	Lower	Upper	RPD	
PCE	98	99	2	80	84	5	-	-	-	73	131	20	
TCE	102	100	2	80	87	8	-	-	-	64	127	20	
1,1-DCE	98	91	8	73	76	4	-	-	-	51	143	20	
Panama City - UltraSeep Field Duplicates													
Compound	SM-T4-4-B5			N/A			N/A			Control Limits			
	1	2	RPD	1	2	RPD	1	2	RPD	RPD			
PCE	< 1.0	< 1.0	0	-	-	-	-	-	-	30			
TCE	< 1.0	< 1.0	0	-	-	-	-	-	-	30			
1,1-DCE	< 1.0	< 1.0	0	-	-	-	-	-	-	30			
Orlando - UltraSeep Matrix Spike/Matrix Spike Duplicates													
Compound	7/7/2005			7/8/2005			N/A			Control Limits			
	MS	MSD	RPD	MS	MSD	RPD	MS	MSD	RPD	Lower	Upper	RPD	
PCE	99	97	3	102	100	2	-	-	-	56	138	20	
TCE	108	103	5	105	104	1	-	-	-	50	147	20	
cis-DCE	116	111	4	125	129	3	-	-	-	59	149	20	
trans-DCE	115	118	3	107	115	7	-	-	-	41	157	20	
VC	99	100	1	103	100	3	-	-	-	20	187	20	
Orlando - UltraSeep Field Duplicates													
Compound	SM-T3-7-B7			SM-T2-5-B6			SM-T2-3-B3			Control Limits			
	1	2	RPD	1	2	RPD	1	2	RPD	RPD			
PCE	< 1.0	< 1.0	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30			
TCE	< 10	4.5	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30			
cis-DCE	470	500	6	6.4	7	9	1.6	1.4	13	30			
trans-DCE	< 10	3	0	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30			
VC	47	50.1	6	< 1.0	< 1.0	0	< 1.0	< 1.0	0	30			

Table 4-4. UltraSeep system performance summary.

Type	Criteria	Expected	Actual - Panama City	Actual - Orlando
Qualitative	Mobilize, operate, and demobilization the equipment	As specified in the Demo Plan.		
	• Pre-calibrate sensors	Within spec.	✓ Calibrated within spec prior to shipment	✓ Calibrated within spec prior to shipment
	• Pre-clean sampler	Based on CoC	✓ Pre-cleaned for VOCs	✓ Pre-cleaned for VOCs
	• Ship to site	Arrive in working order	✓ Arrived in working order	✓ Arrived in working order
Quantitative	Position, deploy, and operate the equipment over site-relevant time period	As specified in the Demo Plan.		
	• Deployment period	Complete tidal cycle or 24-hrs	Completed 25-hr tidal cycle at each target station	Completed 24 hour deployment at each target station

¹For target analytes PCE, TCE, and 1,1-DCE

²For target analytes PCE, TCE, cis-DCE, trans-DCE, and VC

³Some samples composited to achieve sufficient volume in accordance with Demo Plan

Table 4-4. UltraSeep performance summary. (continued)

Type	Criteria	Expected	Actual - Panama City	Actual - Orlando
Quantitative	Obtain field measurements within specified measurement quality objectives	As specified in the MQOs in the QAPP.		
	• Conductivity	Accuracy: $\leq 2\%$ FS Precision: ≤ 2 mS/cm	Sensor Acc: 0.1 - 0.3 % Sensor Prec: 0.01 - 0.04 mS/cm	Sensor Acc: 0.05 - 1.7 % Sensor Prec: 0.0 - 0.01 mS/cm
	• Temperature	Accuracy: ≤ 0.1 C Precision: ≤ 0.05 C	Sensor Acc: 0.0 - 0.07 C Sensor Prec: 0.01 - 0.03 C	Sensor Acc: 0.0 - 0.08 C Sensor Prec: 0.02 - 0.05 C
	• Flow	Accuracy: ≤ 1 cm/d Precision: ≤ 0.5 cm/d	Sensor Acc: 0.01 - 1.05 cm/d Sensor Prec: 0.3 - 0.45 cm/d	Sensor Acc: 0.0 - 0.5 cm/d Sensor Prec: 0.07 - 0.2 cm/d
	• VOCs - detection limit	PQL: 1-5 ug/L	PQL: 1-5 ug/L	PQL: 1-10 ug/L Increased PQL due to high DCE concentrations required dilution for 8 UltraSeep samples and 3 piezometer sample
	- analytical performance	Surrogate Spike Recovery w/i limits	152 of 152 analyses w/i control limits	255 of 255 analyses w/i control limits
	- bias	Matrix spike recovery w/i limits	12 of 12 analyses w/i control limits ¹	20 of 20 analyses w/i control limits ²
		Lab control spike recovery w/i limits	24 of 24 analyses w/i control limits ¹	39 of 40 analyses w/i control limits ² 1>UCL
	- precision	MSDs w/i limits	6 of 6 analyses w/i control limits ¹	10 of 10 analyses w/i control limits ²
		Field Dups w/i limits	3 of 3 analyses w/i control limits ¹	15 of 15 analyses w/i control limits ²

¹For target analytes PCE, TCE, and 1,1-DCE

²For target analytes PCE, TCE, cis-DCE, trans-DCE, and VC

³Some samples composited to achieve sufficient volume in accordance with Demo Plan

Table 4-4. UltraSeep performance summary. (continued)

Type	Criteria	Expected	Actual - Panama City	Actual - Orlando
Quantitative	Obtain trip and equipment blanks that are free of contamination	As specified in the MQOs in the QAPP.		
	• Equipment rinsate	ND or comparable to rinse water	9 of 9 analyses ND ¹	14 of 15 analyses ND ² cis-DCE >PQL in 1 blank (1.8 ug/L)
	• Trip blank	ND or comparable to pre-trip	6 of 6 analyses ND ¹	NA - analyzed on site
Quantitative and Qualitative	Obtain valid, continuous seepage flow records over required time periods	Based on MQOs for completeness as specified in the QAPP	Successfully obtained valid, continuous seepage flow records over complete tidal cycle	Successfully obtained valid, continuous seepage flow records over complete tidal cycle
	• Flow	Completeness > 95% Validation: qualitatively comparable to level logging piezometers	Flow Completeness: 100% UltraSeep and piezometer samples in general agreement - both systems indicate discharge at target stations - mean discharge rates agree within a factor of about 2	Flow Completeness: 100% UltraSeep and piezometer samples in general agreement - both systems indicate discharge at target stations - mean discharge rates agree within a factor of about 2 - both systems indicate same spatial trend decreasing with distance from shore
Quantitative	Obtain valid discharge water samples of sufficient volume to characterize CoC concentrations during periods of positive seepage	As specified in the MQOs in the QAPP.		
	• VOCs by 8260B	Volume: >80 ml Validation: comparable to shallow piezometers	17 of 17 samples sufficient volume ³ UltraSeep and piezometer samples in agreement - ND for all target analytes at all validation stations	29 of 29 samples sufficient volume ³ UltraSeep and piezometer samples in agreement - probabilities for 2-sided ttest All Stations: no difference P=0.37 Station T2-3: no difference P=0.27 Station T2-5: no difference P=0.36 Station T3-7: no difference P=0.31

¹For target analytes PCE, TCE, and 1,1-DCE

²For target analytes PCE, TCE, cis-DCE, trans-DCE, and VC

Some samples composited to achieve sufficient volume in accordance with Demo Plan

4.3 DATA ANALYSIS, INTERPRETATION, AND EVALUATION

4.3.1 Trident Probe Validation Analysis

Validation measurements for comparison with the Trident probe water sample results are developed using piezometers installed at a subset of the Trident probe stations (Figure 3-19). Water samples are collected synoptically from the Trident probe and the adjacent piezometer. VOC concentrations and water quality characteristics will be compared statistically to assess the general level of agreement or disagreement between the Trident probe samples and the validation samples collected with the piezometer.

The Trident probe and piezometer data are compared using the following procedures:

1. VOC concentrations and sensor measurements will be obtained at each validation station using both methods. At each station, triplicate field samples will be collected using the Trident probe. At one station, triplicate piezometer installations will be made and used to collect similar replicates. These replicate samples for the Trident probe and the piezometers will be used to calculate the variability associated with each method, including any localized spatial heterogeneity.
2. Paired results from each of the methods will be compared on a station-by-station basis.
3. For VOCs, if the results from both methods indicate ND in all replicates at a given station, the results are in agreement, and no further statistical testing is needed.
4. For sensor measurements and detectable VOCs, the two methods will be compared using a two-sided Student's t-Test with $\alpha = 0.05$.

4.3.2 Trident Probe Survey Results—NSA Panama City

The Trident probe was used to map the surface and sub-surface distribution of temperature, conductivity, VOCs, and water quality characteristics at 30 stations (Figure 4-1). Variability within stations was assessed based on triplicate station deployments at station T3-3. Field sample variability was assessed based on field duplicate samples collected at approximately 10% of the stations. Validation of the Trident probe sampling was conducted based on piezometers installed to a depth of 2 ft along the T3 transect. Results for the Trident probe survey, including conductivity and temperature mapping, VOC mapping, water quality characteristics, and validation sampling are presented in Subsections 4.3.2.1 through 4.3.2.3.

4.3.2.1 Trident Probe Conductivity and Temperature Mapping

Results from the Trident probe conductivity and temperature sensors are shown in Table 4-5. Sub-surface measurements were taken at a depth of 2 ft below the sediment surface, and surface water measurements were taken in the overlying surface water within 1 ft of the sediment surface. Each reading represents the average of 6 to 7 individual measurements recorded at the same station. Standard deviations based on these replicate measurements are also given.

Sub-surface conductivity ranged from a low of 5.8 at station T4-4 to a high of 15.3 at station T2-1. Sub-surface temperature ranged from a low of 28.6 at station T4-4 to a high of 30.2 at station T2-1. During the summer, it was expected that areas of groundwater discharge would be characterized by relatively lower conductivity and temperature. Based on the Trident probe conductivity mapping, three areas were identified as potential regions of groundwater discharge (Figure 4-2). These areas included stations T1-3, T3-3, T4-4, and T5-4. Of the three, T4-4 showed the strongest groundwater signal. Based on the conductivity

mapping, the zone of discharge appeared to be limited to a band extending parallel to shore between about 100-300 ft offshore. Water quality analysis of the water samples collected with the Trident probe confirmed the low conductivity at these stations (Tables 4-3 and 4-6). The temperature differences across the site generally prove to be too small to be useful in identifying groundwater discharge zones. The only exception was T4-4, which showed a clearly identifiable lower temperature relative to other areas (Figure 4-3).

4.3.2.2 Trident Probe VOC Mapping

Results from the Trident probe VOC samples are shown in Tables 4-7 through 4-11. Sub-surface samples were collected at a depth of 2 ft below the sediment surface (Figure 4-5), and surface water samples were collected within 1 ft above the sediment surface (Figure 4-9). The primary COC for AOC 1 was DCE. All VOC analytes, including DCE at all Trident probe stations were below the practical quantitation limit (PQL). Concentrations above the method detection limit (MDL), but below the PQL were measured for m,p-Xylene and Naphthalene in the surface water at station T1-5, and for Naphthalene in the sub-surface water at station T5-6. No detectable DCE or other VOCs were measured in the sub-surface or surface water in the groundwater discharge areas identified with the Trident probe sensors (Figures 4-6, 4-7, 4-10, and 4-11).

4.3.2.3 Trident Probe Validation Piezometers

Results from the Trident probe validation piezometer VOC samples are shown in Table 4-12. Validation of the Trident probe sampling was based on piezometers installed to a depth of 2 ft along the T3 transect (Figure 4-8). All VOC analytes, including DCE at all Trident probe validation piezometer stations, were below the PQL and MDL. No detectable DCE or other VOCs were measured in the sub-surface water in the areas of groundwater discharge identified with the Trident probe sensors. The piezometer results validated the Trident probe results.

Table 4-5. Trident probe sub-surface sensor results.

Station ID	Field Rep.	Date	Time	Long. (degrees)	Lat. (degrees)	Station Rep. (n)	Average Subsurf. Temp. (C)	St. Dev. Subsurf. Temp. (C)	Average Subsurf. Cond. (mS/cm)	St. Dev. Subsurf. Cond. (mS/cm)	Average Surface Temp. (C)	St. Dev. Surface Temp. (C)	Average Surface Cond. (mS/cm)	St. Dev. Surface Cond. (mS/cm)
T1-1-SS	1	8/9/2004	10:23:44	-85.75368	30.17840	7	28.899	0.001	13.941	0.007	31.151	0.014	38.471	0.049
T1-2-SS	1	8/9/2004	13:39:59	-85.75337	30.17840	6	29.804	0.003	13.333	0.010	31.607	0.004	42.183	0.041
T1-3-SS	1	8/9/2004	14:50:22	-85.75307	30.17840	6	29.532	0.017	9.552	0.010	31.696	0.008	44.783	0.041
T1-4-SS	1	8/9/2004	16:07:26	-85.75275	30.17842	6	29.576	0.005	14.397	0.010	31.265	0.001	45.050	0.055
T1-5-SS	1	8/9/2004	16:55:46	-85.75243	30.17840	7	29.519	0.007	13.871	0.015	30.978	0.002	45.429	0.049
T1-6-SS	1	8/9/2004	17:39:46	-85.75212	30.17842	6	29.452	0.008	13.112	0.021	30.587	0.003	45.800	0.000
T2-1-SS	1	8/10/2004	11:54:56	-85.75375	30.17812	6	30.159	0.004	15.322	0.013	28.050	0.013	37.583	0.214
T2-2-SS	1	8/10/2004	12:50:14	-85.75343	30.17812	6	29.732	0.005	13.718	0.008	28.560	0.011	42.933	0.186
T2-3-SS	1	8/10/2004	13:33:15	-85.75310	30.17813	6	29.717	0.020	13.362	0.013	28.707	0.002	43.900	0.000
T2-4-SSA	1	8/10/2004	14:18:54	-85.75280	30.17815	7	29.516	0.016	13.677	0.015	28.959	0.004	45.971	0.095
T2-4-SSB	2	8/10/2004	14:21:35	-85.75280	30.17815	7	29.455	0.006	13.680	0.012	28.979	0.003	45.929	0.049
T2-5-SS	1	8/10/2004	15:04:06	-85.75245	30.17817	6	29.467	0.019	13.915	0.008	28.926	0.010	46.300	0.000
T2-6-SS	1	8/10/2004	16:13:54	-85.75222	30.17813	7	29.277	0.005	12.324	0.019	28.896	0.001	46.800	0.000
T3-1-SS	1	8/11/2004	10:10:00	-85.75378	30.17783	7	29.537	0.004	12.917	0.010	28.808	0.024	49.643	0.053
T3-2-SS	1	8/11/2004	11:11:48	-85.75348	30.17783	6	29.358	0.003	12.932	0.033	28.442	0.001	49.283	0.041
T3-3A-SS	1	8/11/2004	12:04:44	-85.75315	30.17787	6	29.273	0.005	12.343	0.015	28.611	0.002	48.900	0.000
T3-3B-SS	1	8/11/2004	12:52:46	-85.75315	30.17785	6	29.215	0.004	10.762	0.008	28.653	0.004	49.450	0.055
T3-3C-SS	1	8/11/2004	13:29:07	-85.75317	30.17783	6	29.329	0.022	10.958	0.015	28.689	0.010	49.467	0.082
T3-4-SS	1	8/11/2004	14:05:27	-85.75283	30.17785	7	29.297	0.018	13.221	0.007	28.689	0.003	49.257	0.053
T3-5-SS	1	8/11/2004	15:01:15	-85.75253	30.17785	6	29.050	0.007	12.567	0.008	28.696	0.001	49.100	0.000
T3-6-SS	1	8/11/2004	16:19:43	-85.75220	30.17787	6	29.218	0.022	13.500	0.022	28.743	0.003	48.867	0.052
T4-1-SS	1	8/12/2004	11:21:50	-85.75362	30.17758	6	29.076	0.006	13.947	0.012	27.530	0.024	39.500	1.459
T4-2-SSA	1	8/12/2004	12:00:47	-85.75328	30.17758	6	29.123	0.008	12.420	0.017	27.844	0.002	46.383	0.041
T4-2-SSB	2	8/12/2004	12:02:58	-85.75330	30.17758	6	29.089	0.004	12.417	0.022	27.821	0.005	46.317	0.041
T4-3-SS	1	8/12/2004	12:51:17	-85.75298	30.17763	6	29.033	0.008	13.817	0.012	28.278	0.005	45.050	0.055
T4-4-SS	1	8/12/2004	13:21:12	-85.75267	30.17762	6	28.640	0.011	5.835	0.008	28.536	0.018	42.017	0.041
T4-5-SS	1	8/12/2004	13:50:23	-85.75237	30.17760	6	29.016	0.009	14.018	0.008	28.830	0.000	42.500	0.000
T4-6-SS	1	8/12/2004	14:16:56	-85.75205	30.17762	6	29.000	0.011	14.552	0.019	28.808	0.002	43.900	0.000
T5-1-SS	1	8/12/2004	14:41:23	-85.75342	30.17730	6	29.038	0.008	13.135	0.027	29.856	0.021	39.367	0.082
T5-2-SS	1	8/12/2004	15:12:23	-85.75308	30.17732	6	28.871	0.005	12.437	0.014	29.228	0.021	41.583	0.041
T5-3-SS	1	8/12/2004	15:41:54	-85.75280	30.17732	7	29.081	0.010	12.999	0.007	29.155	0.001	43.200	0.000
T5-4-SS	1	8/12/2004	16:16:20	-85.75247	30.17732	6	28.929	0.011	11.782	0.026	29.384	0.000	43.300	0.000
T5-5-SS	1	8/12/2004	16:45:19	-85.75215	30.17733	6	28.934	0.010	13.543	0.023	29.006	0.001	44.600	0.000
T5-6-SSA	1	8/12/2004	17:23:35	-85.75183	30.17733	6	28.906	0.005	14.420	0.009	28.959	0.001	45.100	0.000
T5-6-SSB	2	8/12/2004	17:26:30	-85.75183	30.17733	6	28.875	0.002	14.418	0.017	28.959	0.002	45.183	0.041

Table 4-6. Trident probe sub-surface porewater water quality results.

Site ID	Field Rep	Sample Temp. (C)	Conductivity (mS/cm)	TDS (ppm)	pH	ORP (mV)	Dissolved Oxygen (ppm)
T1-1-SS	1	32.8	39.02	37.75	7.32	-67	NA
T1-2-SS	1	31.0	43.14	44.41	7.05	-246	NA
T1-3-SS	1	31.0	32.21	33.33	6.82	-244	NA
T1-4-SS	1	29.3	46.53	48.69	7.31	-234	NA
T1-5-SS	1	29.3	46.75	48.97	7.53	-173	NA
T1-6-SS	1	29.0	45.93	48.03	7.61	-157	NA
T2-1-SS	1	29.8	45.41	45.59	7.70	130	1.99
T2-2-SS	1	30.4	44.40	46.07	6.79	-230	2.42
T2-3-SS	1	31.2	45.68	47.47	6.94	-278	0.25
T2-4-SSA	1	30.5	45.25	47.05	7.36	-206	1.12
T2-4-SSB	2	30.4	45.81	47.72	7.41	-206	0.88
T2-5-SS	1	29.0	45.05	46.99	7.34	-208	1.36
T2-6-SS	1	29.0	42.91	44.43	7.03	-196	0.46
T3-1-SS	1	27.2	44.44	46.44	7.04	-6	2.07
T3-2-SS	1	29.1	41.73	43.01	7.20	-274	0.05
T3-3A-SS	1	29.3	43.78	45.41	7.46	-173	2.73
T3-3B-SS	1	28.1	38.13	38.83	7.18	-195	2.15
T3-3C-SS	1	28.1	35.81	36.05	7.25	-147	3.06
T3-4-SS	1	28.7	43.43	45.08	7.51	-183	2.29
T3-5-SS	1	29.9	38.25	38.21	6.94	-75	2.54
T3-6-SS	1	29.0	44.70	46.55	7.69	-85	1.66
T4-1-SS	1	27.1	41.79	43.23	7.44	-119	2.09
T4-2-SSA	1	28.6	42.68	44.20	7.04	-257	0.25
T4-2-SSB	2	28.3	41.37	42.66	7.13	-217	0.02
T4-3-SS	1	30.3	42.80	44.11	7.14	-134	1.25
T4-4-SS	1	29.2	22.42	20.80	6.97	-109	1.17
T4-5-SS	1	29.9	46.31	48.37	7.50	-185	1.35
T4-6-SS	1	28.9	46.31	48.52	7.31	-218	1.26
T5-1-SS	1	29.7	40.02	40.91	7.40	-171	0.59
T5-2-SS	1	29.6	42.32	43.67	7.09	-177	0.99
T5-3-SS	1	28.9	43.67	45.38	7.19	-201	0.84
T5-4-SS	1	29.3	36.99	36.89	7.21	-243	0.47
T5-5-SS	1	30.8	46.19	48.10	7.22	-217	0.39
T5-6-SSA	1	30.4	47.18	49.33	7.52	-184	0.84
T5-6-SSB	2	29.6	47.50	49.82	3.03	109	0.95

Table 4-7. Trident probe VOC results for transect T1.

			Trident T1													
			Sub-Surface Water							Surface Water						
			TD-T1-1-SS-A/B	TD-T1-2-SS-A/B	TD-T1-3-SS-A/B	TD-T1-4-SS-A/B	TD-T1-5-SS-A/B	TD-T1-6-SS-A/B		TD-T1-1-S-A/B	TD-T1-2-S-A/B	TD-T1-3-S-A/B	TD-T1-4-S-A/B	TD-T1-5-S-A/B	TD-T1-6-S-A/B	
Field Replicate	MDL	PQL	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Date of Analysis:			8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1	1	1	1	1	1	1	1
1,1-Dichloroethene	0.5	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	0.3	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Trichloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Tetrachloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
m,p-Xylene	0.4	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	0.9 I	< 1.0
o-Xylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Naphthalene	2.4	5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	4.0 I	< 5.0

All concentrations reported in µg/L.

Table 4-8. Trident probe VOC results for transect T2.

			Trident T2															
			Sub-Surface Water							Surface Water								
			TD-T2-1-SS-A/B	TD-T2-2-SS-A/B	TD-T2-3-SS-A/B	TD-T2-4-SS-A/B	TD-T2-5-SS-A/B	TD-T2-6-SS-A/B	TD-T2-1-S-A/B	TD-T2-2-S-A/B	TD-T2-3-S-A/B	TD-T2-4-S-A/B	TD-T2-5-S-A/B	TD-T2-6-S-A/B	TD-T2-1-SS-A/B	TD-T2-2-S-A/B	TD-T2-3-S-A/B	TD-T2-4-S-A/B
Field Replicate	MDL	PQL	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1	1
Date of Analysis:			8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04	8/12/04
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1,1-Dichloroethene	0.5	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	0.3	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Trichloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Tetrachloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
m,p-Xylene	0.4	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Naphthalene	2.4	5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0

All concentrations reported in µg/L.

Table 4-9. Trident probe VOC results for transect T3.

Field Replicate	MDL	PQL	Trident T3															
			Sub-Surface Water								Surface Water							
			TD-T3-1-SS-A/B	TD-T3-2-SS-A/B	TD-T3-3-SS1-A/B	TD-T3-3-SS2-A/B	TD-T3-3-SS3-A/B	TD-T3-4-SS-A/B	TD-T3-5-SS-A/B	TD-T3-6-SS-A/B	TD-T3-1-S-A/B	TD-T3-2-S-A/B	TD-T3-3-S1-A/B	TD-T3-3-S2-A/B	TD-T3-3-S3-A/B	TD-T3-4-S-A/B	TD-T3-5-S-A/B	TD-T3-6-S-A/B
Field Replicate	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Date of Analysis:	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04	8/13/04
Matrix:	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1,1-Dichloroethene	0.5	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	0.3	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Trichloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Tetrachloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
m,p-Xylene	0.4	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Naphthalene	2.4	5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0

All concentrations reported in µg/L.

Table 4-10. Trident probe VOC results for transect T4.

			Trident T4															
			Sub-Surface Water							Surface Water								
			TD-T4-1-SS-A/B	TD-T4-2-SS-A/B	TD-T4-3-SS-A/B	TD-T4-4-SS-A/B	TD-T4-5-SS-A/B	TD-T4-6-SS-A/B	TD-T4-1-S-A/B	TD-T4-2-S-A/B	TD-T4-3-S-A/B	TD-T4-4-S-A/B	TD-T4-5-S-A/B	TD-T4-6-S-A/B	TD-T4-1-SS-A/B	TD-T4-2-S-A/B	TD-T4-3-S-A/B	TD-T4-4-S-A/B
Field Replicate	MDL	PQL	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1
Date of Analysis:			8/14/04	8/14/04	8/14/04	8/14/04	8/14/04	8/14/04	8/13/04	8/14/04	8/14/04	8/14/04	8/14/04	8/14/04	8/14/04	8/14/04	8/14/04	8/14/04
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1,1-Dichloroethene	0.5	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	0.3	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Trichloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Tetrachloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
m,p-Xylene	0.4	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Naphthalene	2.4	5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0

All concentrations reported in µg/L.

Table 4-11. Trident probe VOC results for transect T5.

			Trident T5														
			Sub-Surface Water							Surface Water							
			TD-T5-1-SS-A/B	TD-T5-2-SS-A/B	TD-T5-3-SS-A/B	TD-T5-4-SS-A/B	TD-T5-5-SS-A/B	TD-T5-6-SS-A/B	TD-T5-6-SS-A/B	TD-T5-1-S-A/B	TD-T5-2-S-A/B	TD-T5-3-S-A/B	TD-T5-4-S-A/B	TD-T5-5-S-A/B	TD-T5-6-S-A/B	TD-T5-6-S-A/B	
Field Replicate	MDL	PQL	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2
Date of Analysis:			8/14/04	8/14/04	8/14/04	8/14/04	8/15/04	8/16/04	8/16/04	8/14/04	8/14/04	8/14/04	8/14/04	8/14/04	8/15/04	8/15/04	
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1,1-Dichloroethene	0.5	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	0.3	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Trichloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Tetrachloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
m,p-Xylene	0.4	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Naphthalene	2.4	5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	4.1 1	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0

All concentrations reported in µg/L.

Table 4-12. Trident probe validation piezometer VOC results.

			2 ft Piezometers T3															
			PZ-T3-1-SS-A/B		PZ-T3-2-SS-A/B		PZ-T3-3-SS1-A/B		PZ-T3-3-SS2-A/B		PZ-T3-3-SS3-A/B		PZ-T3-4-SS-A/B		PZ-T3-5-SS-A/B		PZ-T3-6-SS-A/B	
Field Replicate	MDL	PQL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Date of Analysis:			38212	38212	38212	38212	38212	38212	38212	38212	38212	38212	38212	38212	38212	38212	38212	
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	
Dilution Factor:			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1,1-Dichloroethene	0.5	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
1,1-Dichloroethane	0.3	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
1,1,1-Trichloroethane	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Benzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Trichloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Toluene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Tetrachloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Ethylbenzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
m,p-Xylene	0.4	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
o-Xylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Naphthalene	2.4	5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	

All concentrations reported in $\mu\text{g/L}$.



Figure 4-1. Deployment of the Trident probe in St. Andrew Bay.

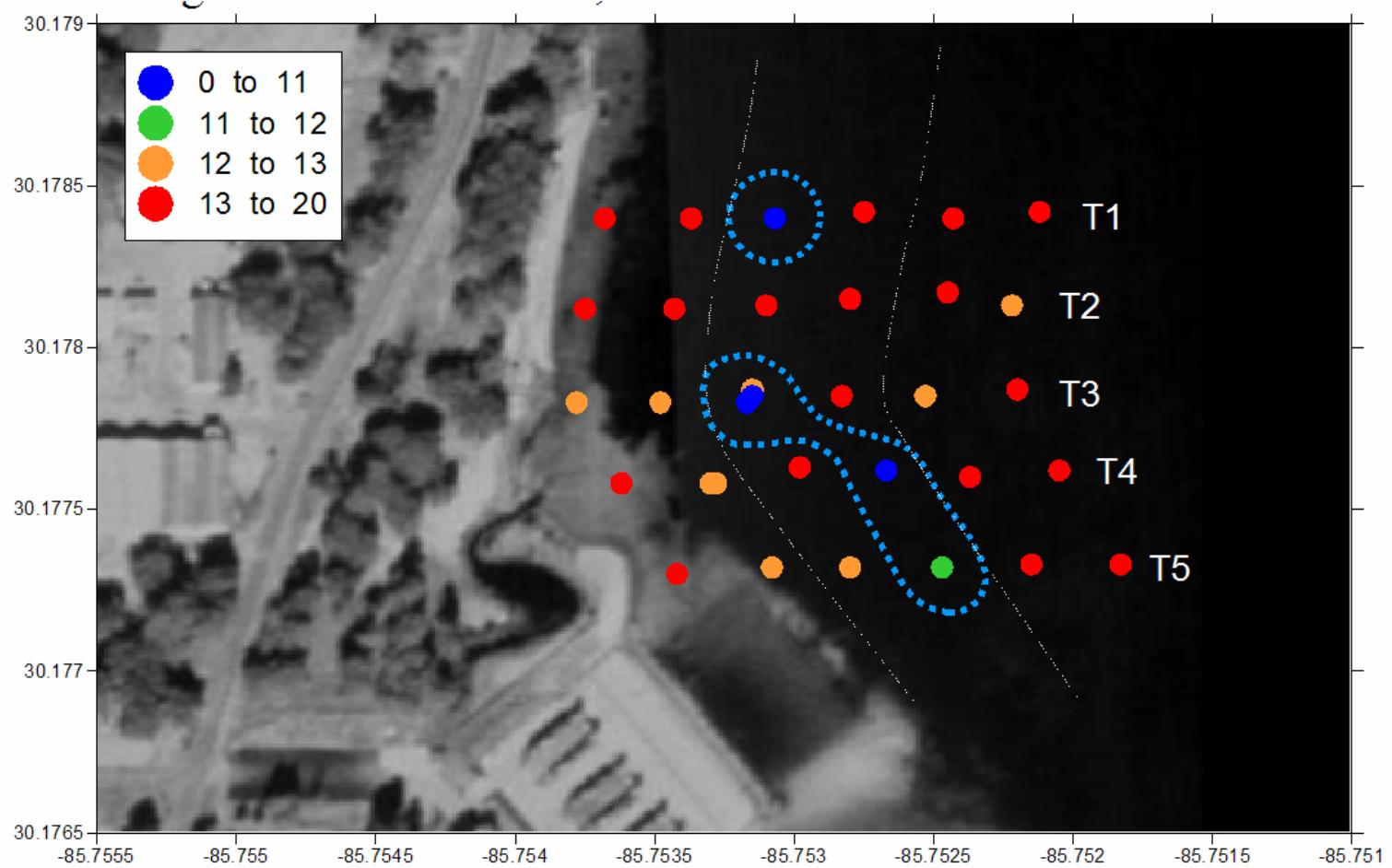


Figure 4-2. Trident probe conductivity map (mS/cm) for the area offshore from AOC1. The heavy blue dashed line indicates the localized discharge zones based on conductivity. The white dotted lines indicate the general offshore band where potential discharge was found.

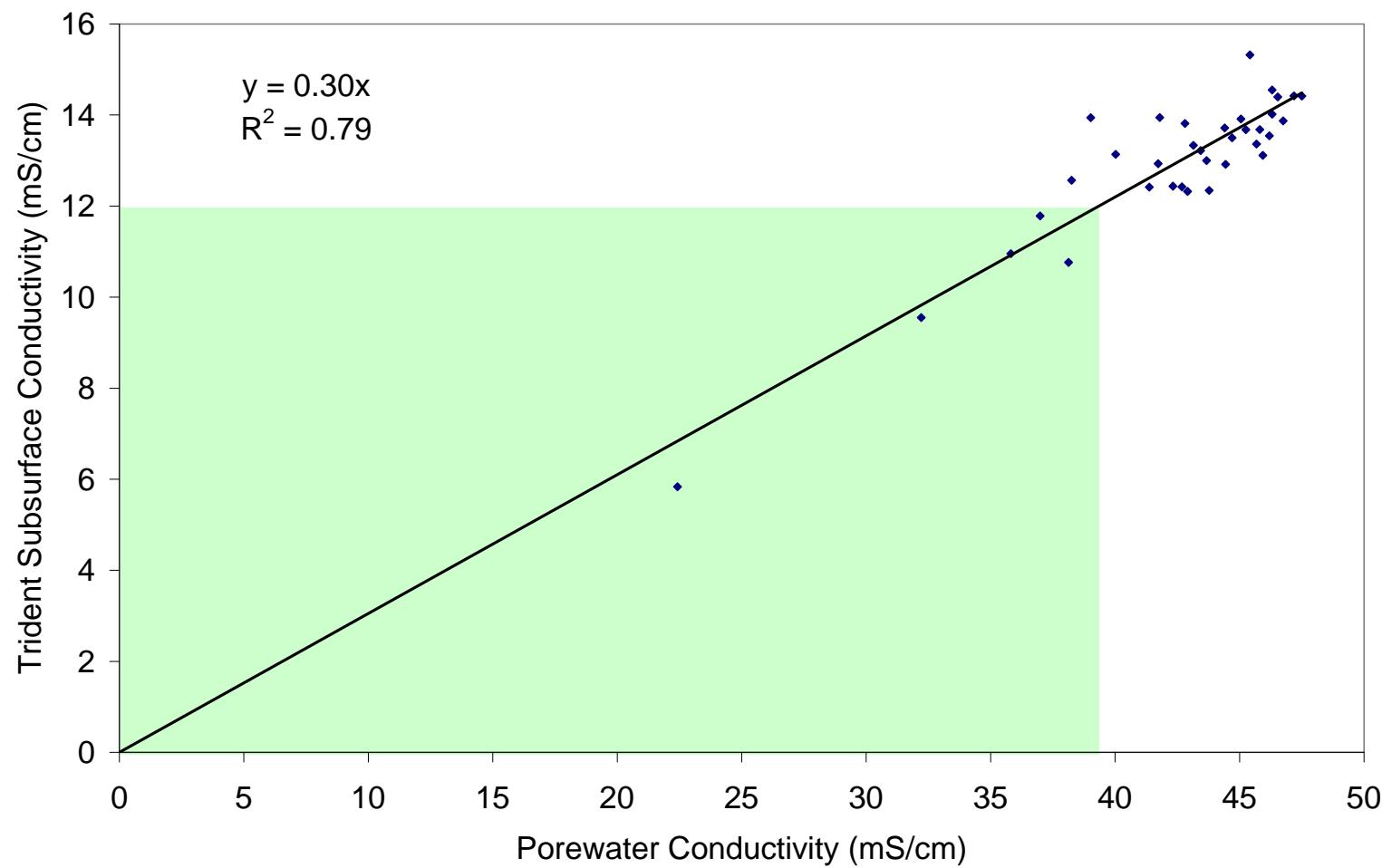


Figure 4-3. Relationship between Trident probe sub-surface conductivity and porewater conductivity.

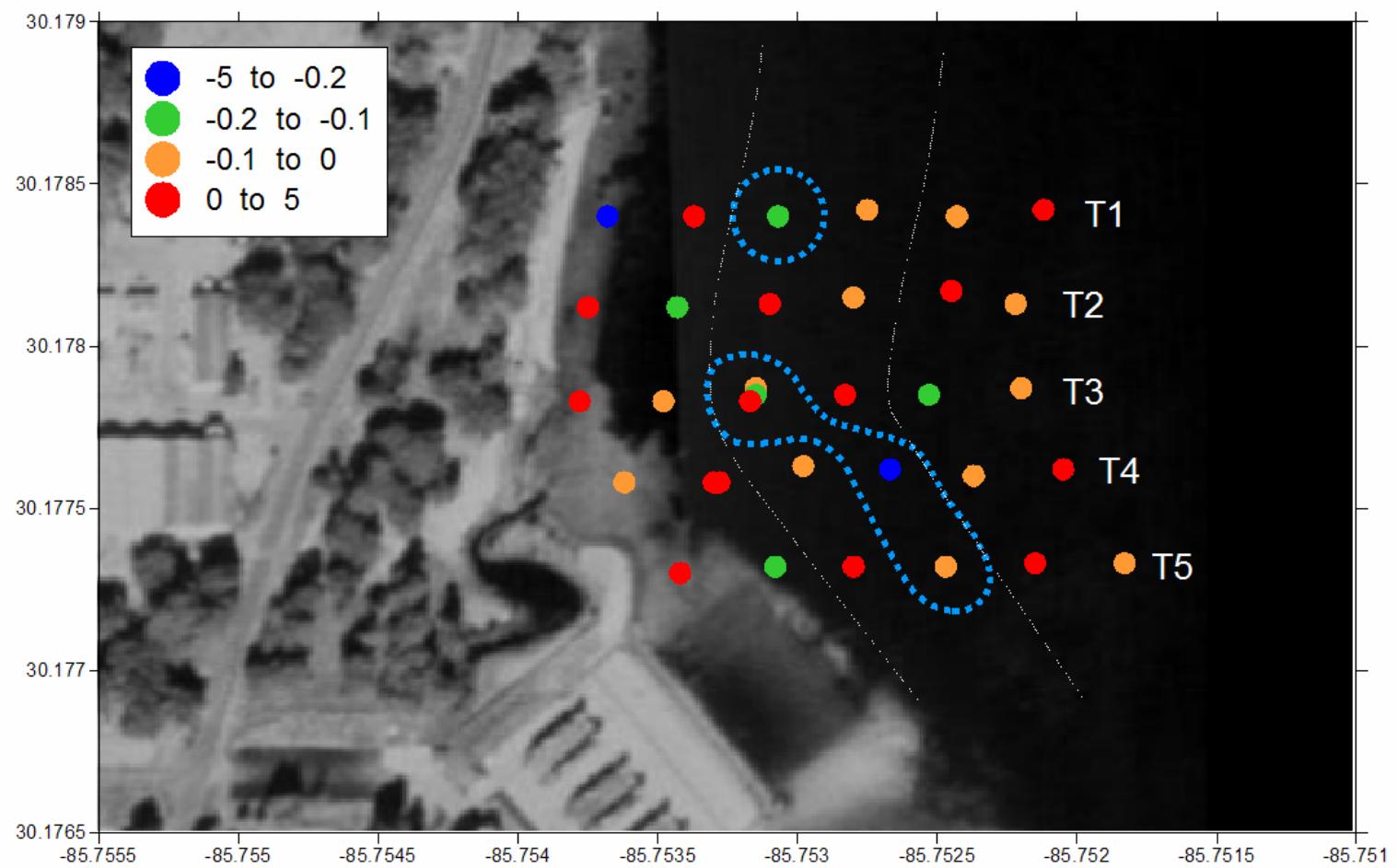


Figure 4-4. Trident probe temperature anomaly map ($^{\circ}$ C) for the area offshore from AOC1. The heavy blue dashed line indicates the localized discharge zones based on conductivity. The white dotted lines indicate the general offshore band where potential discharge was found.

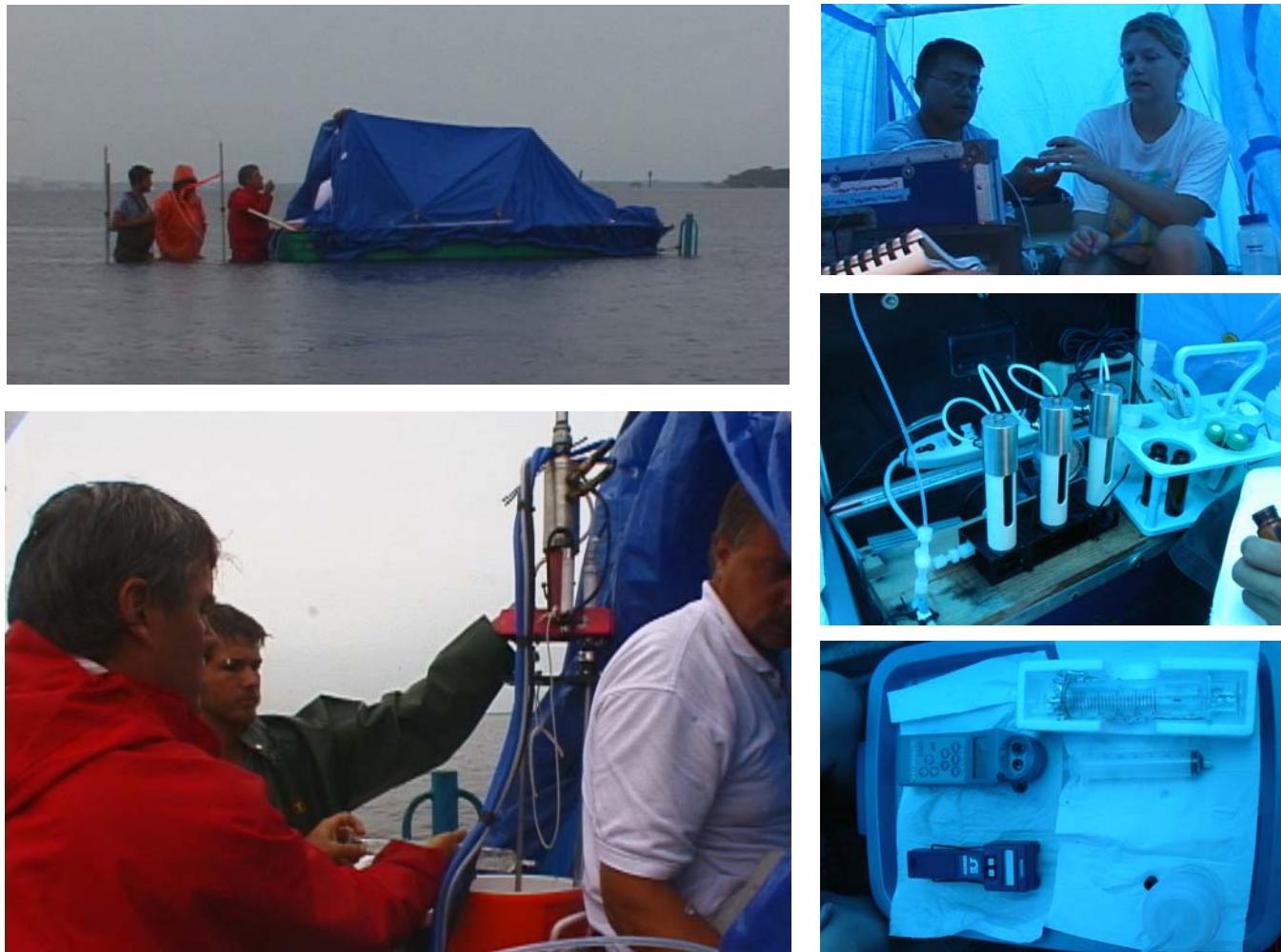


Figure 4-5. Trident probe sub-surface porewater sampling by small boat and wading (upper left), collecting samples (upper right), VOA sampling manifold (middle right), water quality analyzers (lower right), and decon station (lower left).

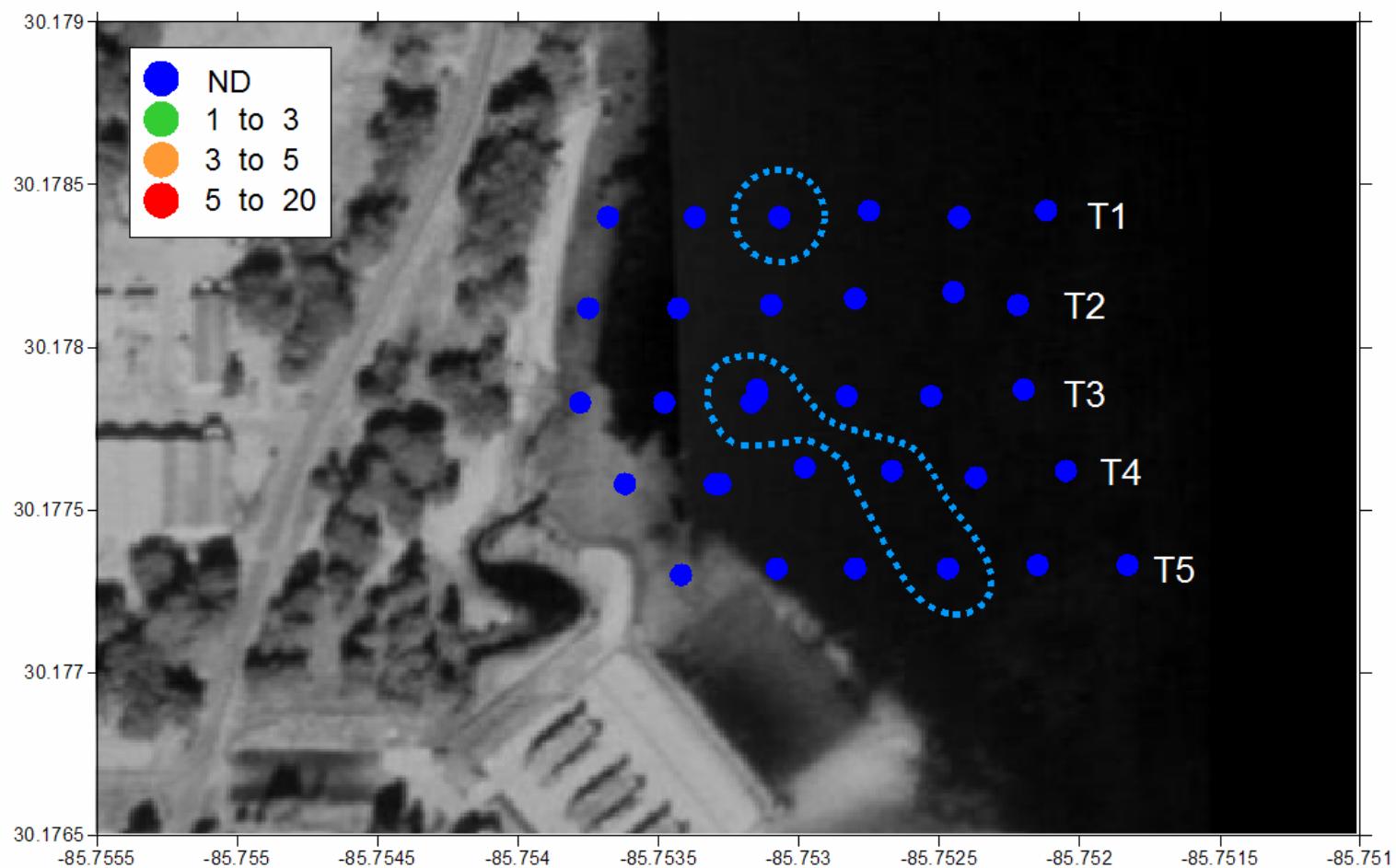


Figure 4-6. Trident probe sub-surface 1,1-DCE map ($\mu\text{g/L}$) for area offshore from AOC 1. Heavy blue dashed line indicates localized discharge zones based on conductivity.

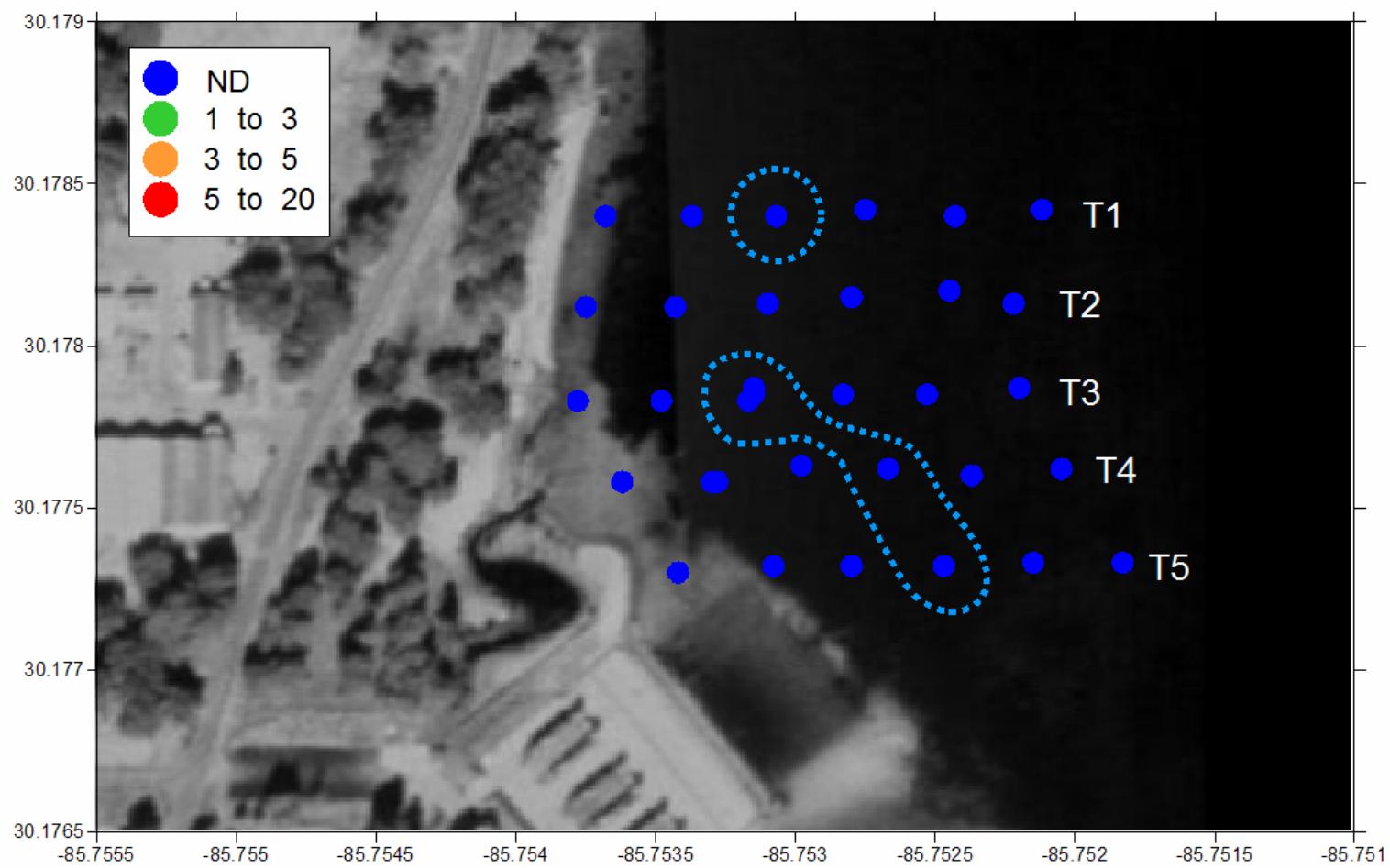


Figure 4-7. Trident probe sub-surface TCE map ($\mu\text{g/L}$) for area offshore from AOC 1. Heavy blue dashed line indicates localized discharge zones based on conductivity.



Figure 4-8. Trident probe validation piezometers prior to installation (lower left), installed along transect 3 (upper left), at replicate station T3-3 (upper right), and being sampled (lower right).

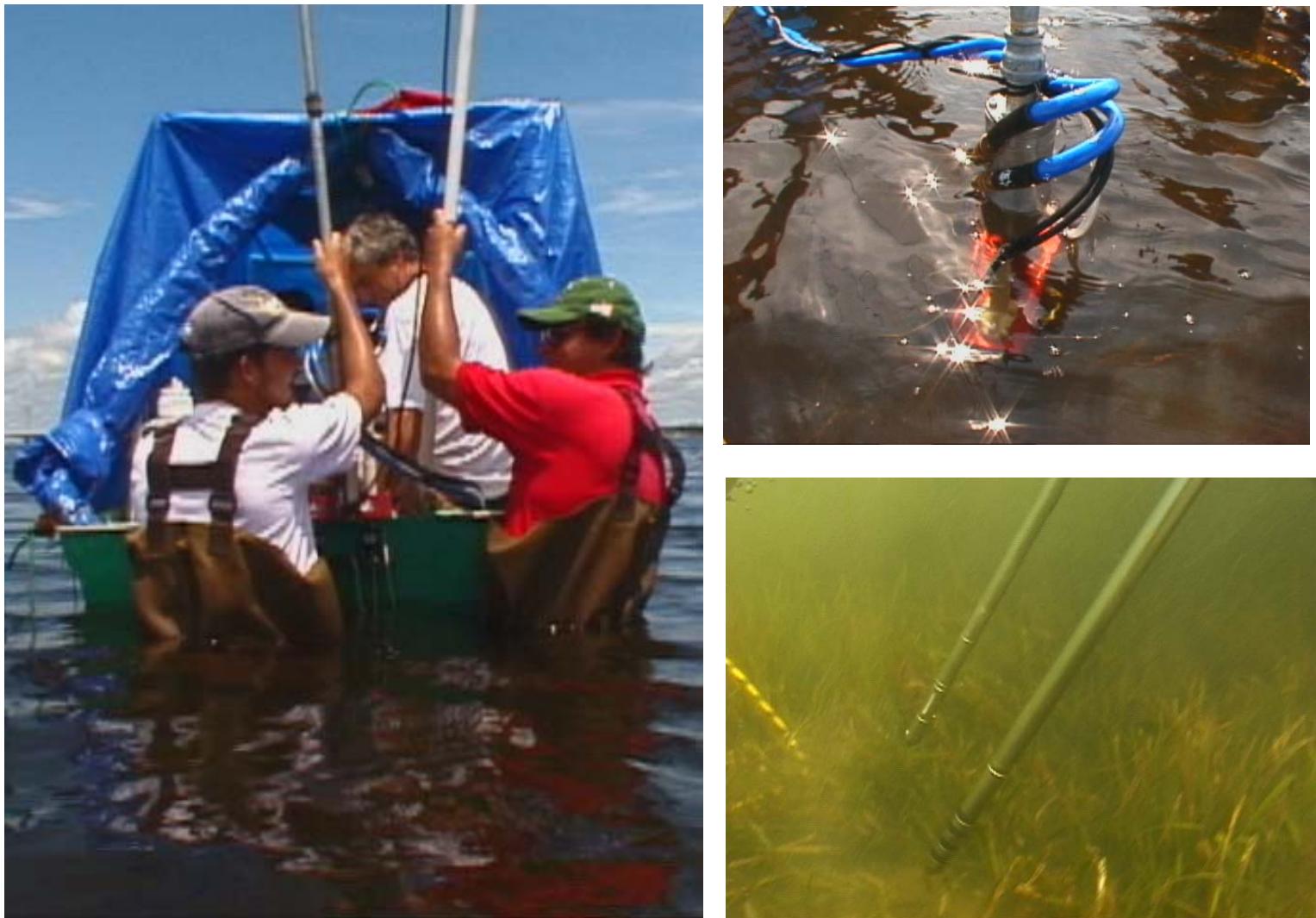


Figure 4-9. Trident probe surface water sampling.

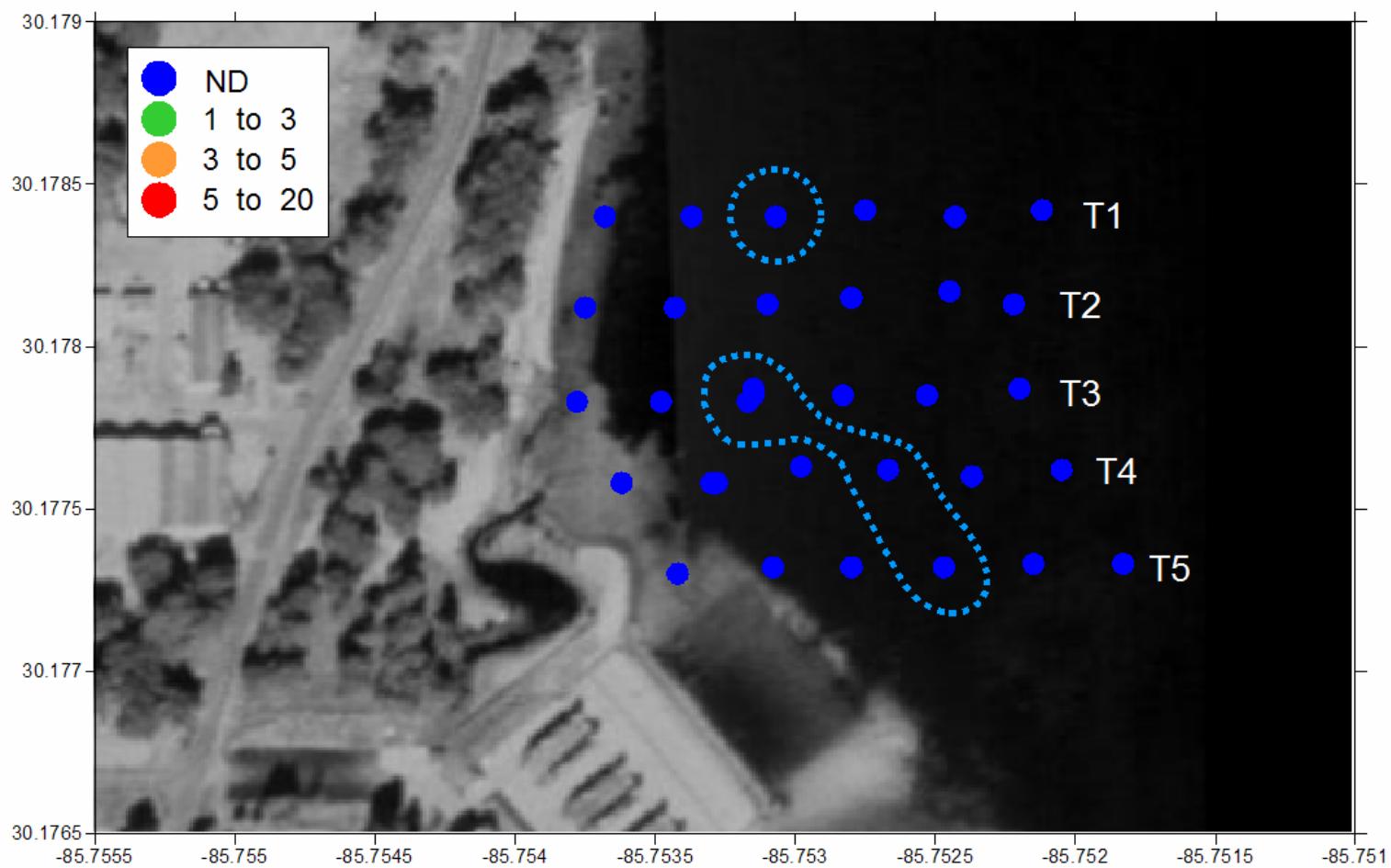


Figure 4-10. Trident probe surface water 1,1-DCE map ($\mu\text{g}/\text{L}$) for area offshore from AOC 1. Heavy blue dashed line indicates localized discharge zones based on conductivity.

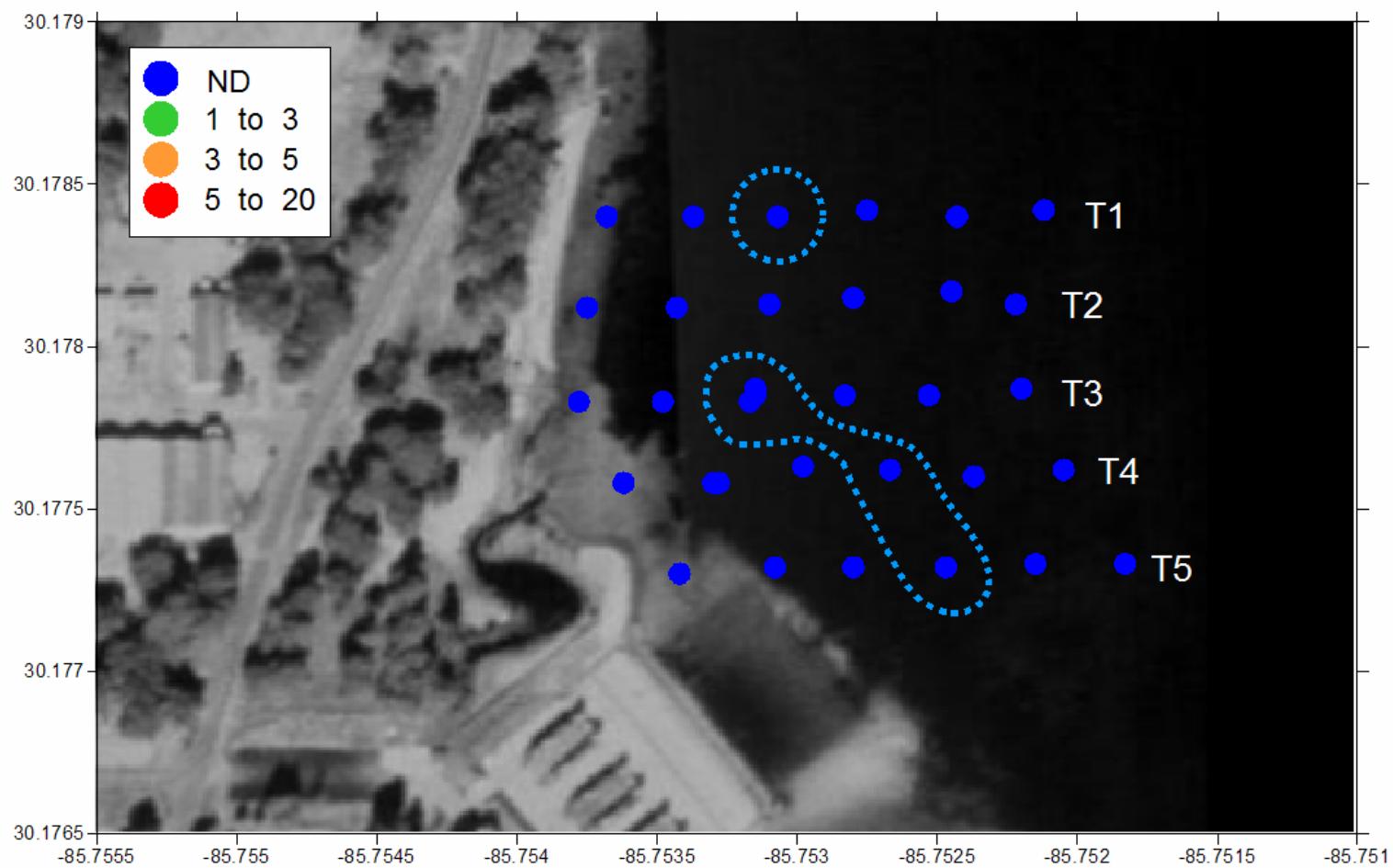


Figure 4-11. Trident probe surface water TCE map ($\mu\text{g}/\text{L}$) for area offshore from AOC 1. Heavy blue dashed line indicates localized discharge zones based on conductivity.

4.3.3 Trident Probe Survey Results–NTC Orlando

The Trident probe was used to map the surface and sub-surface distribution of temperature, conductivity, VOCs, and water quality characteristics at 31 stations (Figure 3-23). Variability within stations was assessed based on triplicate station deployments at station T3-5. Field sample variability was assessed based on field duplicate samples collected at approximately 10% of the stations. Validation of the Trident probe sampling was conducted based on piezometers installed to a depth of 2 ft along the T3 transect. Trident probe survey results, including conductivity and temperature mapping, VOC mapping, water quality characteristics, and validation sampling, are presented in Subsections 4.3.3.1 through 4.3.3.3.

4.3.3.1 Trident Probe Conductivity and Temperature Mapping

Trident probe conductivity and temperature sensor results are shown in Table 4-13. Sub-surface conductivity was too low to be detected by the Trident probe sensor due to the lake's freshwater characteristics. Sub-surface measurements were taken at a depth of 2 ft below the sediment surface, and surface water measurements were taken in the overlying surface water within 1 ft of the sediment surface. Each reading represents the average of 6 to 7 individual measurements recorded at the same station. Standard deviations based on these replicate measurements are also given.

Sub-surface temperature ranged from a low of 22.6 at station T2-1 to a high of 26.9 at station T5-3. During the summer, it was expected that groundwater discharge areas would be characterized by relatively lower temperature. Based on the Trident probe temperature mapping, two areas were identified as potential regions of groundwater discharge (Figure 4-13). The primary zone appeared to be limited to a band parallel to the shoreline between 50 to 100 ft and extending near shore. A secondary discharge zone extended 200 to 300 ft offshore which includes most of the outer transect stations. The low sub-surface temperatures in the inshore zone were considered to be more likely due to groundwater discharge, while the offshore zone temperatures may have been related to groundwater discharge or to the deeper depth of the lake at these stations.

4.3.3.3 Trident Probe VOC Mapping

Results from the Trident probe VOC samples are shown below. Sub-surface samples were collected at a depth of 2 ft below the sediment surface, and surface water samples were collected within 1 ft above the sediment surface (Figures 4-1 and 4-14). The primary COCs for OU 4 was PCE and its breakdown products.

At transect 1 (T1), no detectable PCE or its breakdown products were measured in the sub-surface or surface water in the areas of groundwater discharge identified by the Trident probe sensors (Tables 4-15 and 4-16). At T2, PCE levels above the practical quantitation limit (PQL) were detected in the sub-surface water at station T2-5 (Table 4-17). Other VOC analytes were detected in the sub-surface water at T2 as well. Moderate levels of TCE, *cis*-DCE, and VC were detected at stations T2-3 and T2-5 (Tables 4-17 and 4-18).

At T3, elevated concentrations of *cis*-DCE were measured at the sub-surface and surface water samples at station T3-7. Other VOCs such as TCE and VC were also detected at the sub-surface and surface water. In addition, toluene, *trans*-1,3-Dichloropropene, 1,2,3-Trichloropropane (TCP), and 1,2-Dichloroethane were also present at the sub-surface and surface water that were above the PQL (Tables 4-19 and 4-20). PCE, *cis*-DCE and VC in the sub-surface and surface water samples at T4 were detected at stations T4-5 and T4-6 (Tables 4-21 and 4-22).

For T5, no detectable PCE and other VOCs were measured in the sub-surface and surface water samples. However, concentrations above the PQL of *m,p*-xylene, isopropylbenzene, and *n*-propylbenzene were measured at detectable levels on the surface water sample at station T5-4 (Tables 4-23 and 4-24). Trident probe sub-surface VOC maps (in µg/L) for PCE, TCE, DCE, and VC are shown in Figures 4-15 through 4-18.

In general, presence of VOCs in the subsurface were limited to potential groundwater discharge areas as characterized by the Trident probe sub-surface temperature mapping. This correspondence indicates that the VOCs are potentially borne by groundwater to the lake interface. Based on this correspondence of potential groundwater discharge and sub-surface VOC detection, three stations, including T3-7, T2-5, and T2-3, were identified as likely candidates for UltraSeep deployment.

4.3.3.3 Trident Probe Validation Piezometers

Results from the Trident probe validation piezometer VOC samples are shown in Table 4-25. The Trident probe sampling results were based on piezometers installed to a depth of 2 ft along the T3 transect. VOC analytes, including PCE from most of the Trident probe validation piezometer stations, were below the PQL and MDL. However, elevated levels of *cis*-DCE were detected in the sub-surface water in the groundwater discharge areas identified with the Trident probe sensors at station T3-7. TCE, and 1,2-Dichloroethane (above the PQL) were also identified.

The piezometer results compared favorably with the results obtained from the Trident probe (Figure 4-19). For TCE, both methods showed low-level detections at T3-6, with a slightly lower concentration in the Trident probe compared to the piezometer. At T3-7, the Trident probe TCE result was masked by the large DCE signal, but was determined to be <20 µg/L which was consistent with the piezometer detection of 13 µg/L. The Trident probe and the piezometer indicated ND at all other validation stations for TCE. For *cis*-DCE, both methods showed detections of comparable concentration levels at T3-6 and T3-7. Trident probe concentrations were slightly higher than the piezometer results at both stations. At all other validation stations, both methods indicated ND for *cis*-DCE. Neither method detected PCE and VC at any of the validation stations.

Table 4-13. Trident probe sub-surface sensor results.

Station ID	Field Rep	Date	Time	Long degrees	Lat degrees	Station Rep	Ave Subsurf Temp (°C)	StDev Subsurf Temp (°C)	Ave Subsurf Cond (mS/cm)	StDev Subsurf Cond (mS/cm)	Ave Surface Temp (°C)	StDev Surface Temp (°C)	Ave Surface Cond (mS/cm)	StDev Surface Cond (mS/cm)
T1-1	1	6/27/05	13:05:49	-81.34900	28.56127	6	23.049	0.018	na	na	26.577	0.015	na	na
T1-2	1	6/27/05	13:21:31	-81.34877	28.56128	6	24.511	0.014	na	na	27.971	0.009	na	na
T1-3	1	6/27/05	13:32:56	-81.34855	28.56128	6	24.679	0.051	na	na	28.114	0.037	na	na
T1-4	1	6/27/05	13:44:20	-81.34832	28.56133	6	24.919	0.040	na	na	27.791	0.003	na	na
T1-5	1	6/27/05	13:55:46	-81.34810	28.56128	6	24.730	0.021	na	na	27.627	0.024	na	na
T1-6	1	6/28/05	12:48:26	-81.34792	28.56126	6	25.016	0.011	na	na	26.908	0.010	na	na
T1-7	1	6/28/05	13:02:59	-81.34780	28.56128	6	23.924	0.012	na	na	28.245	0.028	na	na
T2-1	1	6/27/05	14:48:04	-81.34900	28.56107	6	22.630	0.029	na	na	25.295	0.011	na	na
T2-2	1	6/27/05	14:36:34	-81.34877	28.56110	6	24.236	0.062	na	na	27.256	0.017	na	na
T2-3	1	6/27/05	14:27:35	-81.34855	28.56108	6	24.490	0.052	na	na	27.874	0.080	na	na
T2-4	1	6/27/05	14:19:00	-81.34828	28.56112	6	24.743	0.048	na	na	28.301	0.009	na	na
T2-5	1	6/27/05	14:09:24	-81.34805	28.56107	6	24.379	0.014	na	na	28.846	0.011	na	na
T2-6	1	6/28/05	12:06:19	-81.34792	28.56108	6	24.020	0.008	na	na	26.577	0.025	na	na
T2-7	1	6/28/05	12:18:02	-81.34778	28.56107	6	23.070	0.010	na	na	25.015	0.002	na	na
T3-2	1	6/27/05	16:23:43	-81.34875	28.56093	7	24.437	0.006	na	na	27.814	0.014	na	na
T3-3	1	6/27/05	16:36:40	-81.34853	28.56095	7	25.324	0.013	na	na	27.958	0.042	na	na
T3-3	2	6/29/05	17:41:12	-81.34848	28.56098	7	25.260	0.001	na	na	27.911	0.005	na	na
T3-4	1	6/27/05	16:46:02	-81.34833	28.56095	6	25.986	0.011	na	na	29.163	0.038	na	na
T3-5A	1	6/29/05	12:59:47	-81.34812	28.56095	7	24.316	0.001	na	na	28.699	0.007	na	na
T3-5B	1	6/29/05	13:37:44	-81.34812	28.56095	7	24.393	0.003	na	na	28.489	0.014	na	na
T3-5C	1	6/29/05	14:37:08	-81.34812	28.56093	6	24.509	0.002	na	na	28.008	0.021	na	na
T3-6	1	6/28/05	10:30:12	-81.34788	28.56097	6	22.774	0.006	na	na	24.397	0.027	na	na
T3-7	1	6/28/05	11:02:58	-81.34772	28.56095	6	23.041	0.008	na	na	24.960	0.001	na	na

Conductivity measurements were not available due to the lake's freshwater environment.

Table 4-13. Trident probe sub-surface sensor results (continued)

Station ID	Field Rep	Date	Time	Long degrees	Lat degrees	Station Rep	Ave Subsurf Temp (°C)	StDev Subsurf Temp (°C)	Ave Subsurf Cond (mS/cm)	StDev Subsurf Cond (mS/cm)	Ave Surface Temp (°C)	StDev Surface Temp (°C)	Ave Surface Cond (mS/cm)	StDev Surface Cond (mS/cm)
T4-1	1	6/27/05	17:44:32	-81.34903	28.56077	7	23.111	0.025	na	na	26.411	0.028	na	na
T4-2	1	6/27/05	17:33:44	-81.34880	28.56075	6	25.193	0.016	na	na	27.936	0.007	na	na
T4-3	1	6/27/05	17:23:16	-81.34855	28.56078	7	26.062	0.017	na	na	28.141	0.007	na	na
T4-3	2	7/1/05	12:08:11	-81.34835	28.56075	6	26.101	0.001	na	na	29.082	0.003	na	na
T4-4	1	6/27/05	17:13:45	-81.34830	28.56080	6	26.500	0.014	na	na	29.715	0.014	na	na
T4-5	1	6/27/05	17:06:15	-81.34810	28.56080	6	25.518	0.016	na	na	29.608	0.023	na	na
T4-6	1	6/28/05	13:43:45	-81.34796	28.56078	6	23.599	0.008	na	na	26.333	0.004	na	na
T5-1	1	6/27/05	17:59:14	-81.34900	28.56065	7	24.782	0.016	na	na	27.945	0.012	na	na
T5-1	2	7/2/05	11:10:01	-81.34900	28.56063	6	25.029	0.000	na	na	27.661	0.017	na	na
T5-2	1	6/27/05	18:08:35	-81.34880	28.56060	7	25.535	0.017	na	na	28.294	0.010	na	na
T5-3	1	6/27/05	18:16:48	-81.34857	28.56060	7	26.895	0.014	na	na	29.724	0.019	na	na
T5-4	1	6/27/05	18:26:36	-81.34830	28.56062	6	25.626	0.014	na	na	29.736	0.009	na	na
T5-5	1	6/28/05	13:36:23	-81.34809	28.56059	6	22.756	0.002	na	na	24.352	0.004	na	na

Table 4-14. Trident probe sub-surface porewater (PW) water quality results.

Site ID	Field Rep	Temperature (° C)	Conductivity (µS/cm)	TDS (ppm)	pH	ORP (mV)	Dissolved Oxygen (ppm)
T1-1-PW	1	32.4	273	100	7.7	12	8.8
T1-2-PW	1	26.6	204	97	6.9	-7	4.0
T1-3-PW	1	28.2	163	77	6.4	-51	6.5
T1-4-PW	1	30.1	139	66	6.6	-88	1.9
T1-5-PW	1	28.0	205	97	5.5	-143	1.5
T1-6-PW	1	33.2	348	167	7.4	-161	6.5
T1-7-PW	1	28.5	132	62	5.6	28	4.0
T2-1-PW	1	31.3	289	138	7.1	14	6.9
T2-2-PW	1	27.5	174	82	6.7	534	4.3
T2-3-PW	1	31.0	212	101	6.7	-19	3.8
T2-4-PW	1	30.7	170	81	6.4	-6	2.6
T2-5-PW	1	28.6	163	77	5.5	-87	3.5
T2-6-PW	1	28.6	164	78	5.8	0	4.9
T2-7-PW	1	27.5	149	70	5.9	-16	2.3
T3-2-PW	1	25.6	210	100	6.7	NA	1.2
T3-3-PW	1	26.6	162	76	6.3	-74	2.0
T3-3-PW	2	26.5	163	77	6.2	-63	1.3
T3-4-PW	1	26.9	135	64	5.8	-50	5.2
T3-5A-PW	1	30.0	150	71	5.1	52	2.0
T3-5B-PW	1	26.7	156	74	5.4	-10	1.9
T3-5C-PW	1	31.9	173	82	5.2	26	2.3
T3-6-PW	1	32.6	139	66	5.2	67	3.8
T3-7-PW	1	34.0	137	65	5.3	27	3.4
T4-1-PW	1	32.0	283	135	7.4	12	8.6
T4-2-PW	1	27.9	143	68	7.0	-36	5.1
T4-3-PW	1	31.3	137	65	5.3	47	2.4
T4-3-PW	2	29.7	139	66	5.1	56	2.7
T4-4-PW	1	28.9	141	67	5.5	50	1.7
T4-5-PW	1	28.4	74	35	5.3	-69	2.5
T4-6-PW	1	28.2	80	38	6.2	-29	7.6
T5-1-PW	1	30.8	183	87	6.8	-60	8.8
T5-1-PW	2	28.3	182	86	6.7	-53	6.7
T5-2-PW	1	28.5	192	91	6.9	-52	2.6
T5-3-PW	1	29.9	183	87	5.7	45	2.7
T5-4-PW	1	28.8	99	46	5.2	-34	1.4
T5-5-PW	1	28.3	84	39	5.8	16	2.4

Table 4-15. Trident probe sub-surface porewater (PW) VOC results for transect 1.

			Trident T1 Sub-surface Porewater (PW)						
Units for water: ug/L.			TD-T1-1-PW	TD-T1-2-PW	TD-T1-3-PW	TD-T1-4-PW	TD-T1-5-PW	TD-T1-6-PW	TD-T1-7-PW
Field Replicate	MDL	PQL	1	1	1	1	1	1	1
Date of Analysis:			7/5/05	7/3/05	7/2/05	7/2/05	6/30/05	7/3/05	7/3/05
Matrix:			Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
<i>trans</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromochloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations reported in µg/L.

Table 4-16. Trident probe surface water (SW) VOC results for transect 1.

			Trident T1 Surface Water (SW)						
			TD-T1-1-SW	TD-T1-2-SW	TD-T1-3-SW	TD-T1-4-SW	TD-T1-5-SW	TD-T1-6-SW	TD-T1-7-SW
Units for water: ug/L.									
Field Replicate	MDL	PQL	1	1	1	1	1	1	1
Date of Analysis:			7/5/05	7/3/05	7/3/05	7/2/05	6/30/05	7/3/05	7/3/05
Matrix:			Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
<i>trans</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromochlormethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations reported in µg/L.

Table 4-17. Trident probe sub-surface porewater (PW) VOC results for transect 2.

			Trident T2 Sub-surface Porewater (PW)						
			TD-T2-1-PW	TD-T2-2-PW	TD-T2-3-PW	TD-T2-4-PW	TD-T2-5-PW	TD-T2-6-PW	TD-T2-7-PW
Units for water: ug/L.									
Field Replicate	MDL	PQL	1	1	1	1	1	1	1
Date of Analysis:			7/5/05	7/3/05	7/2/05	7/2/05	6/30/05	7/3/05	7/3/05
Matrix:			Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	56.4	<1.0	<1.0	<1.0	<1.0
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
<i>trans</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	70	<1.0	66	<1.0	13.6
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	37.3	<1.0	2.7
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	7.9	<1.0	<1.0
Dibromochloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations reported in µg/L.

Table 4-18. Trident probe surface water (SW) VOC results for transect 2.

			Trident T2 Surface Water (SW)						
			TD-T2-1-SW	TD-T2-2-SW	TD-T2-3-SW	TD-T2-4-SW	TD-T2-5-SW	TD-T2-6-SW	TD-T2-7-SW
Units for water: ug/L.			7/5/05	7/3/05	7/3/05	7/2/05	6/30/05	7/3/05	7/3/05
Field Replicate	MDL	PQL	1	1	1	1	1	1	1
Date of Analysis:			Water	Water	Water	Water	Water	Water	Water
Matrix:			1	1	1	1	1	1	1
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
<i>trans</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	0.9 I	<1.0	<1.0	<1.0
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromochlormethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations reported in µg/L.

Table 4-19. Trident probe sub-surface porewater (PW) VOC results for transect 3.

			Trident T3 Sub-surface Porewater (PW)								
Units for water: ug/L.			TD-T3-2-PW	TD-T3-3-PW	TD-T3-3-PW	TD-T3-4-PW	TD-T3-5A-PW	TD-T3-5B-PW	TD-T3-5C-PW	TD-T3-6-PW	TD-T3-7-PW
Field Replicate	MDL	PQL	1	1	2	1	1	1	1	1	1
Date of Analysis:			6/30/05	6/30/05	7/1/05	6/30/05	6/30/05	6/30/05	6/30/05	6/30/05	6/30/05
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1	1	10
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<10
<i>trans</i> -DCE	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
<i>cis</i> -DCE	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	5.3	290
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
1,2-Dichloroethane	<1.0	1	1	1	<1.0	1.1	<1.0	<1.0	<1.0	<1.0	<10
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.1	13
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Dibromochlormethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<50
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10

All concentrations reported in µg/L.

Table 4-20. Trident probe surface water (SW) VOC results for transect 3.

			Trident T3 Surface Water (SW)								
Units for water: ug/L.			TD-T3-2-SW	TD-T3-3-SW	TD-T3-4-SW	TD-T3-5A-SW	TD-T3-5B-SW	TD-T3-5C-SW	TD-T3-6-SW	TD-T3-7-SW	
Field Replicate	MDL	PQL	1	1	2	1	1	1	1	1	1
Date of Analysis:			7/1/05	7/1/05	7/1/05	7/3/05	7/1/05	7/1/05	7/1/05	7/1/05	6/30/05
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1	1	2
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.2	34
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<10
<i>trans</i> -DCE	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
<i>cis</i> -DCE	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	7.3	130
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
1,2-Dichloroethane	<1.0	1	1	1	1	<1.0	<1.0	<1.0	1.2	<1.0	<2.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	6.8	7.3
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	12.3	<2.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Dibromochlormethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<10
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	7	<2.0

All concentrations reported in µg/L.

Table 4-21. Trident probe sub-surface porewater (PW) VOC results for transect 4.

			Trident T4 Sub-surface Porewater (PW)						
			TD-T4-1-PW	TD-T4-2-PW	TD-T4-3-PW	TD-T4-4-PW	TD-T4-5-PW	TD-T4-6-PW	
Units for water: ug/L.			1	1	1	2	1	1	1
Field Replicate	MDL	PQL	7/5/05	7/3/05	7/3/05	7/2/05	7/2/05	6/30/05	7/3/05
Date of Analysis:			Water	Water	Water	Water	Water	Water	Water
Matrix:			1	1	1	1	1	1	1
Dilution Factor:									
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
<i>trans</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	2.4	52.7
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	3.4	4.3
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromochlormethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations reported in µg/L.

Table 4-22. Trident probe surface water (SW) VOC results for transect 4.

			Trident T4 Surface Water (SW)						
			TD-T4-1-SW	TD-T4-2-SW	TD-T4-3-SW	TD-T4-3-SW	TD-T4-4-SW	TD-T4-5-SW	TD-T4-6-SW
Units for water: ug/L.		MDL	PQL	1	1	1	2	1	1
Field Replicate				7/5/05	7/3/05	7/3/05	7/2/05	7/2/05	6/30/05
Date of Analysis:				Water	Water	Water	Water	Water	Water
Matrix:				1	1	1	1	1	1
Dilution Factor:									
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
<i>trans</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	13.6
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromochlormethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations reported in µg/L.

Table 4-23. Trident probe sub-surface porewater (PW) VOC results for transect 5.

			Trident T5 Sub-surface Porewater (PW)					
Units for water: ug/L.			TD-T5-1-PW	TD-T5-1-PW	TD-T5-2-PW	TD-T5-3-PW	TD-T5-4-PW	TD-T5-5-PW
Field Replicate	MDL	PQL	1	2	1	1	1	1
Date of Analysis:			7/5/05	7/5/05	7/3/05	7/3/05	6/30/05	7/3/05
Matrix:			Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
<i>trans</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	0.8 I
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromochlormethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations reported in µg/L.

Table 4-24. Trident probe surface water (SW) VOC results for transect 5.

			Trident T5 Surface Water (SW)					
			TD-T5-1-SW	TD-T5-1-SW	TD-T5-2-SW	TD-T5-3-SW	TD-T5-4-SW	TD-T5-5-SW
Units for water: ug/L.			1	2	1	1	1	1
Field Replicate	MDL	PQL	7/5/05	7/5/05	7/3/05	7/3/05	6/30/05	7/2/05
Date of Analysis:			Water	Water	Water	Water	Water	Water
Matrix:			1	1	1	1	1	1
Dilution Factor:								
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
<i>trans</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,2-Dichloroethene (DCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromochlormethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	1.6	<1.0
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	1	<1.0
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations reported in µg/L.

Table 4-25. Trident probe validation piezometers VOC results at transect 3.

			2 ft PiezometersT3							
Units for water: ug/L.			PZ-T3-2-PW	PZ-T3-3-PW	PZ-T3-4-PW	PZ-T3-5A-PW	PZ-T3-5B-PW	PZ-T3-5C-PW	PZ-T3-6-PW	PZ-T3-7-PW
Field Replicate	MDL	PQL	1	1	1	1	1	1	1	1
Date of Analysis:			6/30/05	6/30/05	6/30/05	6/30/05	6/30/05	6/30/05	6/30/05	6/30/05
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1	20
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Chloromethane	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Chloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Methylene Chloride	<5.0	2	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<20
<i>trans</i> -DCE	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
<i>cis</i> -DCE	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	5.9	390
Chloroform	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
1,2-Dichloroethane	<1.0	1	1.1	1	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.2	<20
1,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Bromodichloromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Dibromochlormethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
1,2-Dibromoethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
1,1,1,2-Tetrachloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Ethylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
<i>m,p</i> -Xylene	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
<i>o</i> -Xylene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Styrene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Isopropylbenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
Bromobenzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20
1,1,2,2-Tetrachloroethane	<5.0	1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<100
1,2,3-Trichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<20

All concentrations reported in µg/L.



Figure 4-12. Field deployment of Trident probe at Lake Druid.

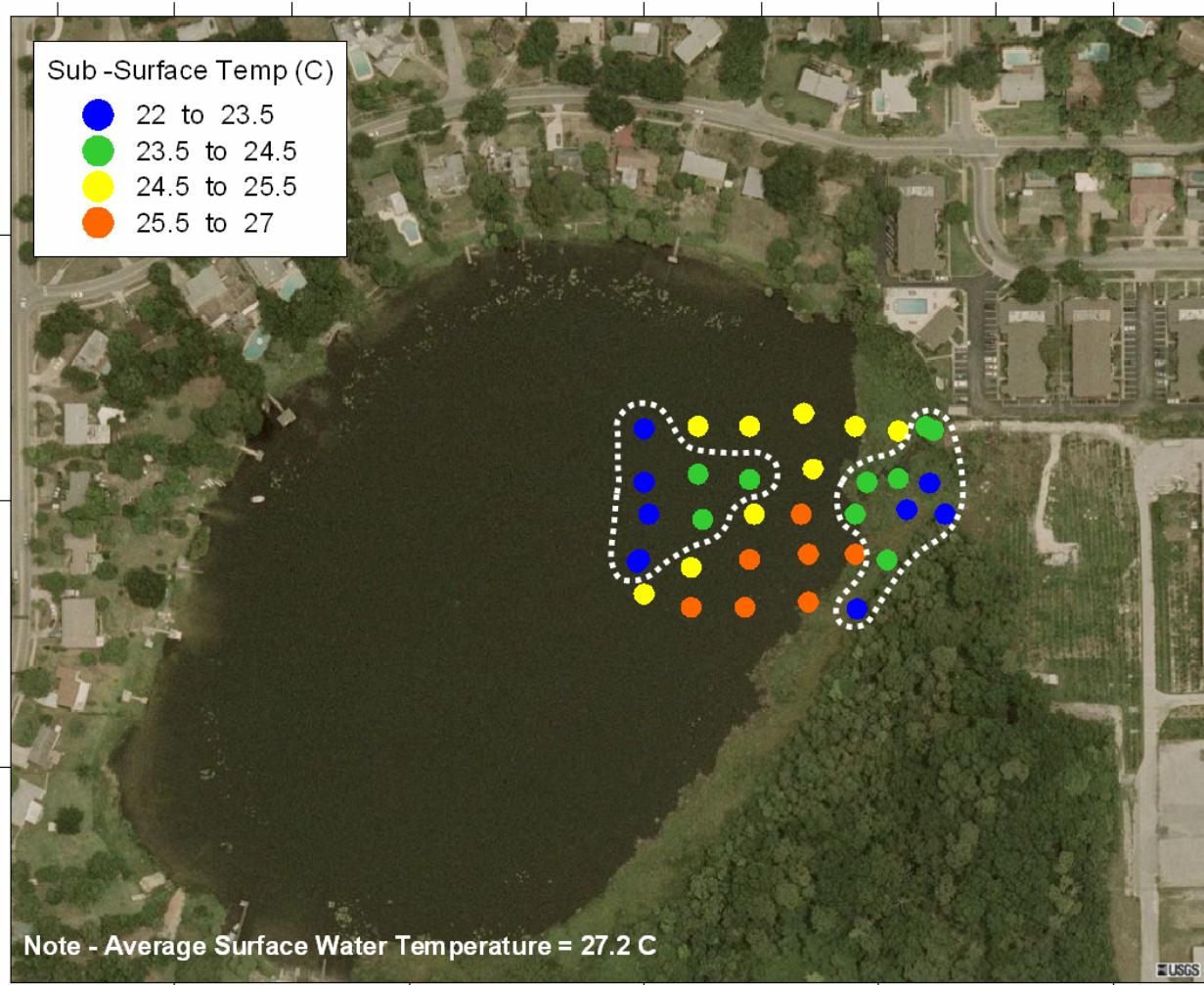


Figure 4-13. Trident probe sub-surface temperature map ($^{\circ}\text{C}$) for the area offshore of OU 4. Dotted lines indicate groundwater discharge zones based on sub-surface temperature.

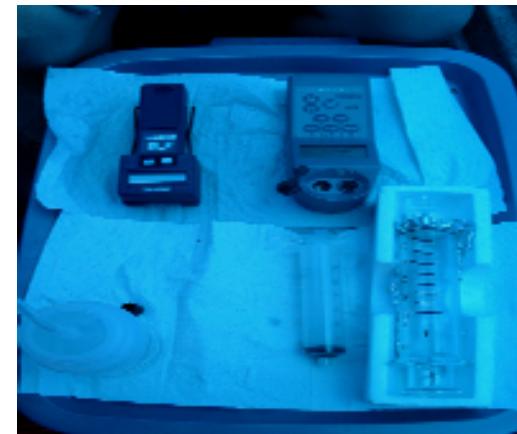
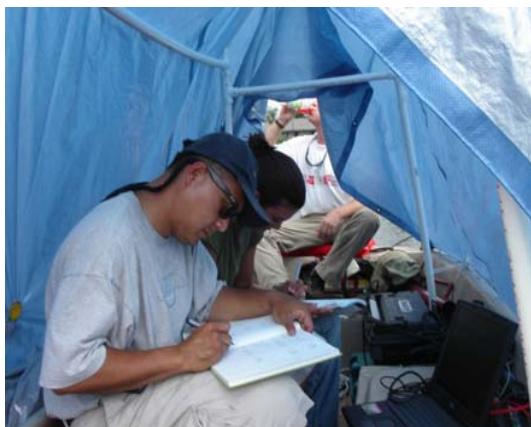


Figure 4-14. Trident probe sampling by small boat (upper left) and wading (upper right), water sampling and data collection (lower left), VOA sampling manifold (lower mid), and water quality analyzers (lower right).

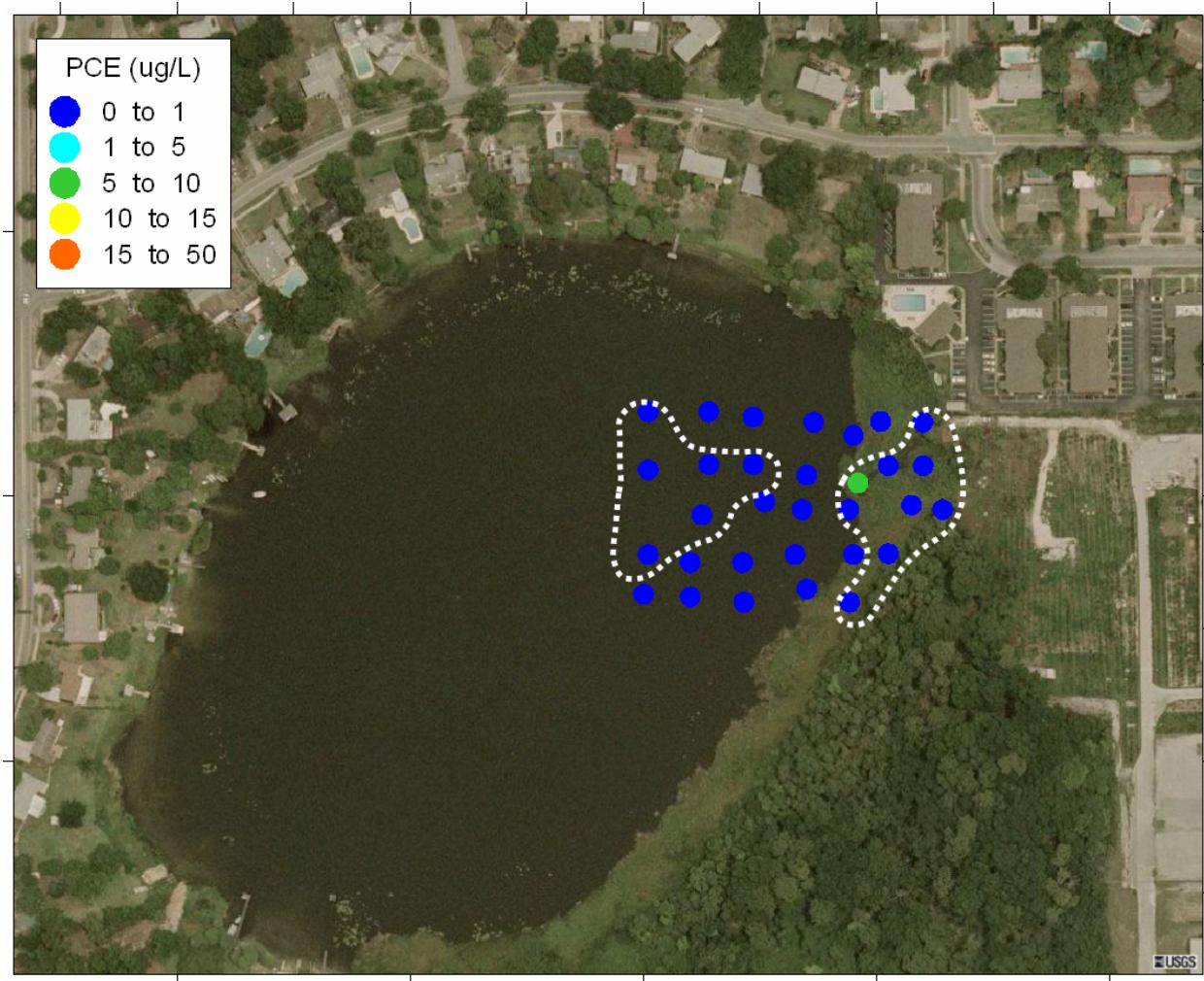


Figure 4-15. Trident probe sub-surface PCE map ($\mu\text{g}/\text{L}$) for the area offshore from OU 4.

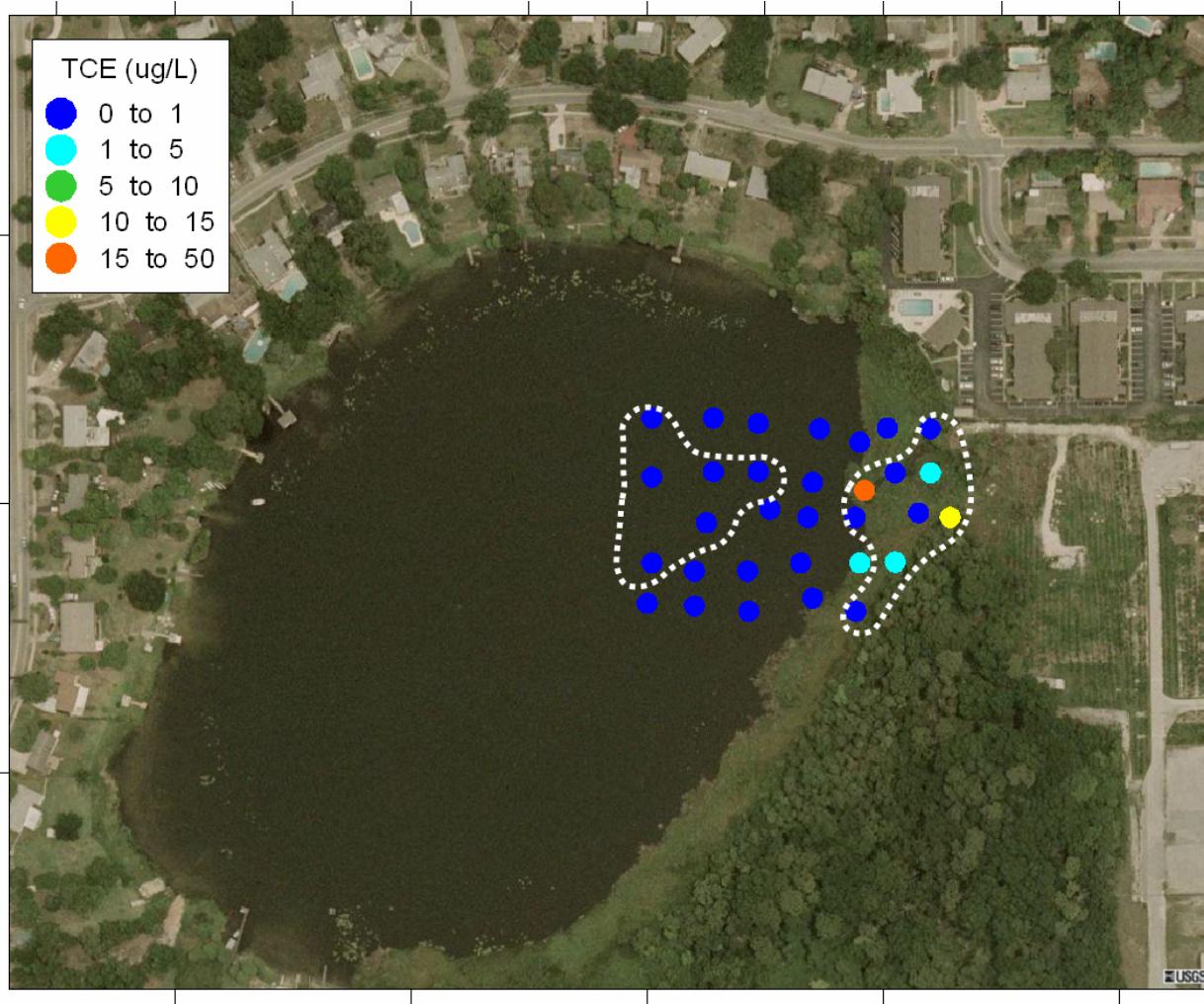


Figure 4-16. Trident probe sub-surface TCE map ($\mu\text{g}/\text{L}$) for the area offshore from OU 4. Dotted lines indicate groundwater discharge zones based on sub-surface temperature.



Figure 4-17. Trident probe sub-surface DCE map ($\mu\text{g/L}$) for the area offshore from OU 4. Dotted lines indicate groundwater discharge zones based on sub-surface temperature.

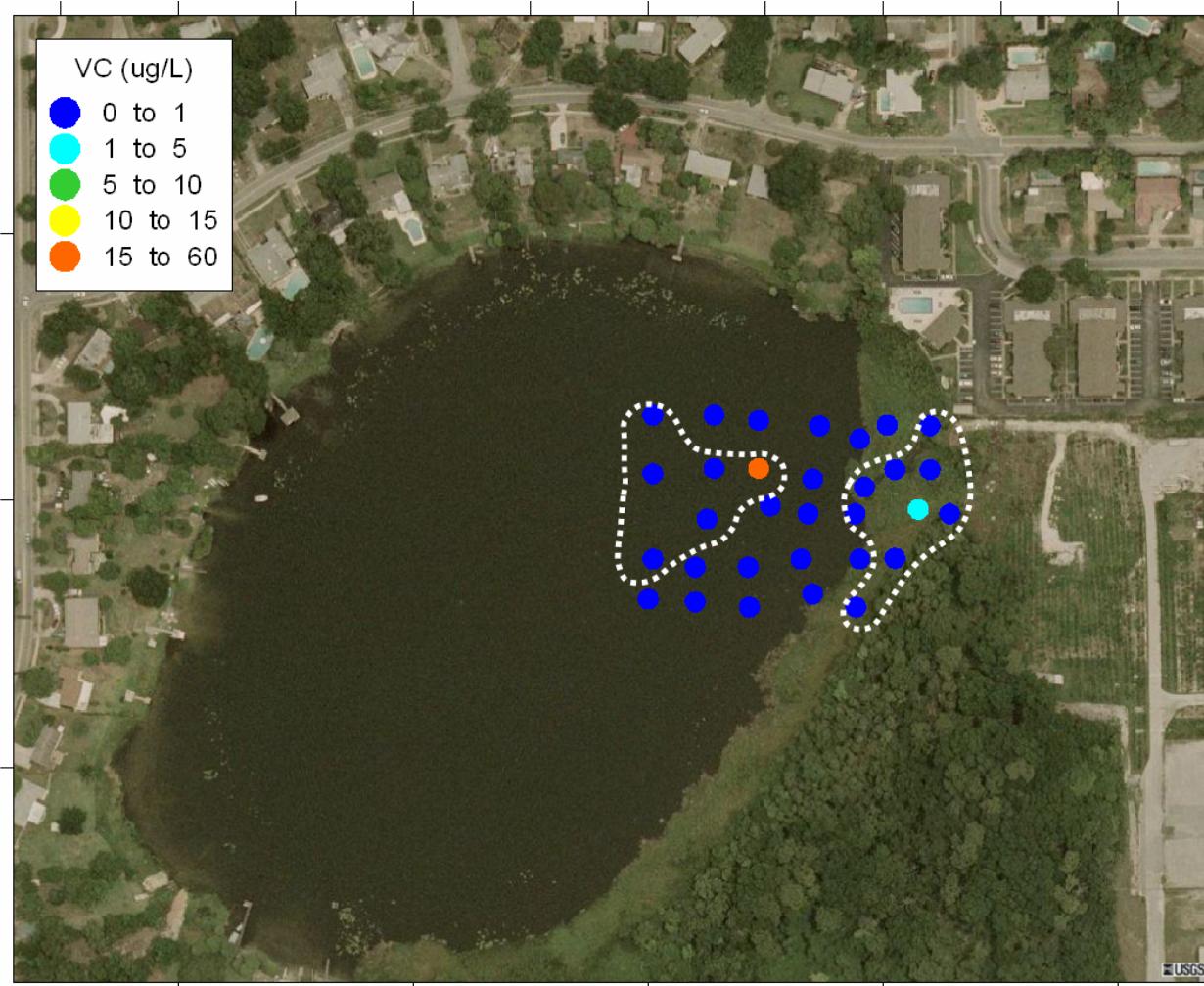


Figure 4-18. Trident probe sub-surface VC map ($\mu\text{g/L}$) for the area offshore from OU 4. Dotted lines indicate groundwater discharge zones based on sub-surface temperature.

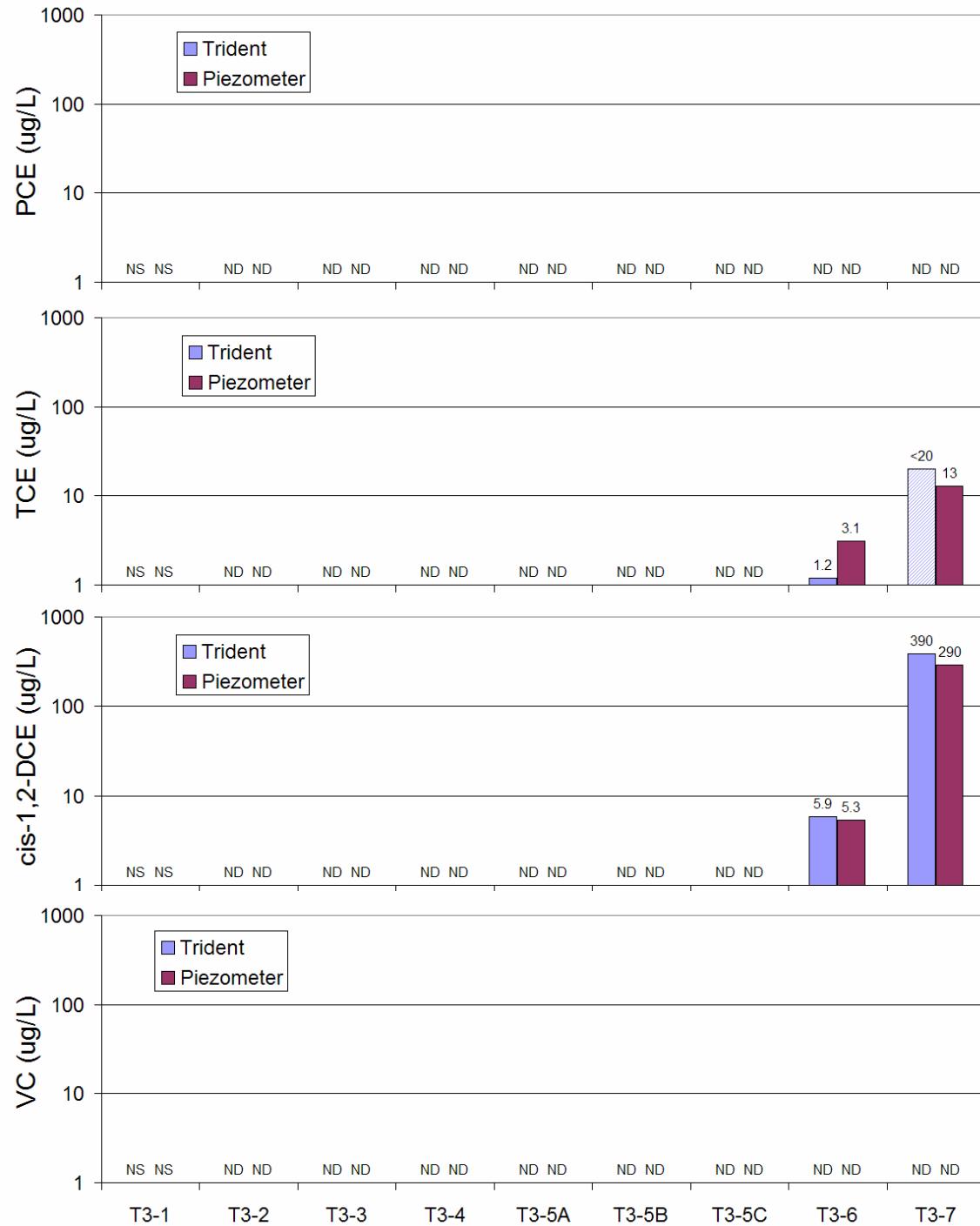


Figure 4-19. Trident probe sub-surface VOC validation along T3.

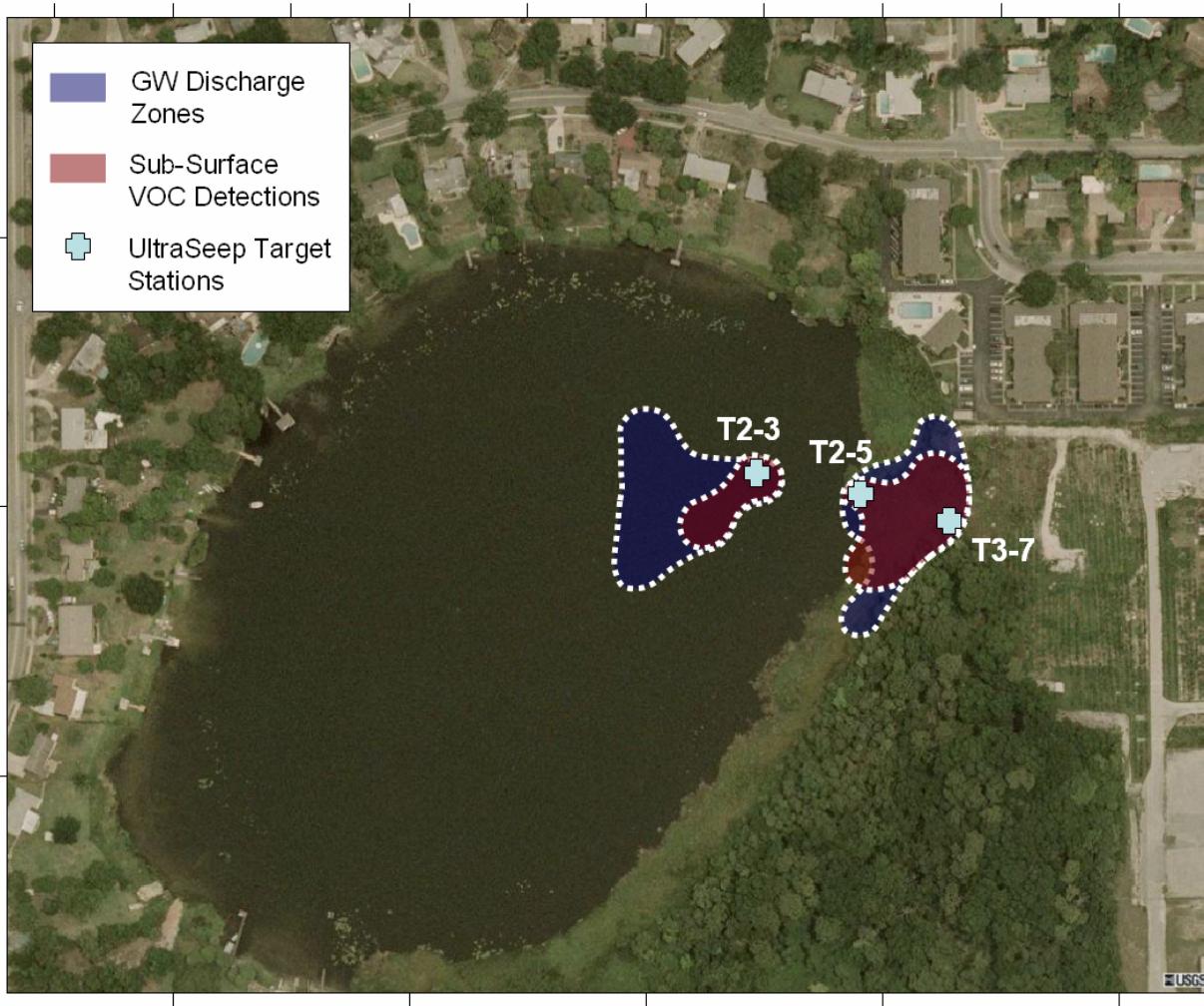


Figure 4-20. Stations selected for UltraSeep flow rate and discharge sampling in relation to groundwater discharge zones and sub-surface VOC detections.

4.4 ULTRASEEP VALIDATION ANALYSIS

Validation measurements for comparison with the UltraSeep flow and water sample results are developed using piezometers installed adjacent to each of the three UltraSeep stations. VOC concentrations and water quality characteristics will be compared qualitatively to assess the general level of agreement or disagreement between the UltraSeep discharge samples and the validation samples collected with the piezometer. During periods of positive seepage, groundwater discharge concentrations of VOCs will be calculated from measured UltraSeep mass balance relationship as

$$C_d = C_f(i) + \frac{V_f}{Q_{gw}} \frac{(C_f(i+1) - C_f(i))}{\Delta t},$$

where

C_d = VOC concentration in the discharge water ($\mu\text{g/L}$)

C_f = VOC concentration in the funnel (measured directly by the UltraSeep) ($\mu\text{g/L}$)

V_f = Volume of the funnel (5236 ml)

Q_{gw} = Discharge of groundwater during time period Δt (measured directly by the UltraSeep) (ml/h)

Δt = Time period of each discharge sample (h)

Calculated flow rates based on water level and hydraulic conductivity measurements in the piezometers will be compared to the direct flow measurements from the UltraSeep. To estimate the specific discharge rate using the piezometer, the following relationship is used (Fetter, 1998):

$$U_{gw} = K \frac{h_p}{d_p},$$

where

U_{gw} = Specific discharge rate (cm/d)

K = Hydraulic conductivity (cm/d)

h_p = Water level measured in the piezometer above or below the surface water (measured directly by the piezometer) (cm)

d_p = depth of the piezometer below the sediment surface (measured during installation) (cm)

The hydraulic conductivity must be estimated for each station with an installed piezometer. This estimate can be derived from the literature or by direct measurement. For the NSA Panama City demonstration, hydraulic conductivities will be measured directly using an in situ falling head test at the end of each validation deployment. To achieve this, the piezometer standpipe is filled instantaneously to an initial level above the equilibrium level. The change in level is then monitored as the piezometer returns to equilibrium. Assuming an unconfined aquifer, the hydraulic conductivity is then calculated as determined by Hvorslev, (1951) and Fetter (1998):

$$K = \frac{r^2 \ln(L_e R)}{2L_e T_0},$$

where

r = radius of the piezometer casing

R = radius of the piezometer screen

L_e = length of the screen section

T_0 = time for water level to fall 37% of the initial height

4.4.1 UltraSeep Survey Results—NSA Panama City

Although no VOCs were detected above PQL during the Trident probe survey, it was decided to proceed with the UltraSeep deployments to confirm discharge in the areas that were identified based on conductivity during the Trident probe survey. Based on the results from the Trident probe survey, three stations were selected for deployment of the UltraSeep. These included (in order of priority) stations T4-4, T3-3, and T1-3.

Station T4-4 was given the highest priority because it had the lowest Trident probe conductivity measurement, the lowest Trident probe temperature measurement, and the low conductivity was confirmed by the water quality analysis of the sub-surface water sample.

Station T3-3 was given the second priority because it had a Trident probe conductivity measurement that was clearly lower than the general background, the low conductivity value was confirmed by the water quality analysis of the sub-surface water sample, and it was on the central transect where previous validation samples for the Trident probe had already been collected.

Station T1-3 was given the third priority because it had the second lowest Trident probe conductivity reading. The reading was confirmed by the water quality analysis of the sub-surface water sample, but it appeared to be on the edge of the grid away from the probable discharge area of the VOC plume.

The first UltraSeep deployment was carried out successfully at station T4-4 (Figure 4-21). However, during the second deployment at station T3-3, a power system malfunction led to a system failure part way through the deployment. The decision was made in the field to resample at T3-3 and abandon the T1-3 deployment due to restrictions on the survey schedule and cost. The UltraSeep sampling validation was based on piezometers installed to a depth of 1 ft at three replicate locations adjacent to each UltraSeep station. Results for the T4-4 and T3-3 deployments are presented in Subsections 4.4.1.1 through 4.4.1.3.

4.4.1.1 UltraSeep Groundwater Discharge

Specific discharge results for stations T4-4 and T3-3 are shown in Figures 4-22 and 4-23. At station T4-4, groundwater discharge rates ranged from about 2 to 8 cm/d. Discharge was always positive (out of the sediment), and maximum discharge occurred near the time of high tide. The mean discharge rate for station T4-4 over the 24-hour period extending from 1600 on 14 August 2004 to 1600 on 15 August 2004 was 5.1 cm/d. At station T3-3, groundwater discharge rates ranged from about 1 to 5 cm/d. As with station T4-4, discharge was always positive (out of the sediment), and maximum discharge occurred near the time of high tide. The mean discharge rate for station T3-3 over the 24-hour period extending from 1300 on 18 August 2004 to 1300 on 19 August 2004 was 2.7 cm/d.

4.4.1.2 UltraSeep VOC Discharge

The UltraSeep collected water samples during periods of positive discharge of ground-water from the sediment. The sampler was configured to collect samples over 10 intervals, with each interval lasting 2.5 hours. At station T4-4, sufficient discharge was present during samples 3 through 10 to conduct analysis for VOCs. For samples 1 and 2, the individual sample volume was insufficient, so the two samples were composited to obtain sufficient volume. The T4-4 results are shown in Table 4-26. All VOC analytes, including DCE in all UltraSeep samples at T4-4, were below the PQL, except for toluene the composite sample T4-4-[B1+B2] (samples 1 and 2), which was detected at a PQL of 1 µg/L.

Concentrations above the MDL, but below the PQL, were measured for toluene in samples 3, 5, and 10 (one replicate of two for sample 5). The source of the low level toluene in these samples is unknown. The equipment blank collected prior to the deployment also showed a low level of toluene (2.6 µg/L), so it is possible that the equipment contributed to the toluene detected in the samples.

At station T3-3, sufficient discharge was present during samples 7 through 10 to conduct analysis for VOCs. For samples 1 through 6, the individual sample volume was insufficient, so samples 1 through 4 were combined into one composite sample (T3-3R-[B1+B2+B3+B4]), and samples 5 and 6 were combined into another composite sample (T3-3R-[B5+B6]). The results for T3-3 are shown in Table 4-27. All VOC analytes, including DCE in all UltraSeep samples at T4-4 were below the PQL with the exception of toluene. Toluene was detected in all six T3-3 samples, with concentrations ranging from 4.1 to 6.0 µg/L. The toluene in these samples is suspected to have been introduced during sample analysis from waterproofing sealants associated with the installation of a new rooftop air conditioner in KB Labs' mobile lab (KB2). Concentrations above the MDL, but below the PQL were measured for m,p-Xylene in the two composite samples and sample 7 (T3-3R-B7).

4.4.1.3 UltraSeep Validation Piezometers

Results from the UltraSeep validation piezometer VOC samples are shown in Table 4-29. The UltraSeep sampling validation was conducted based on piezometers installed to a depth of 1 ft at three replicate locations adjacent to each UltraSeep station. All VOC analytes, including DCE at all UltraSeep T4-4 validation piezometer stations, were below the PQL and MDL. All VOC analytes, including DCE at all UltraSeep T3-3 validation piezometer stations, were below the PQL and MDL, except for toluene. Toluene was detected in all three replicates at the T3-3 UltraSeep station, with concentrations ranging from 3.1 to 4.3 µg/L. The toluene in these samples is suspected to have been introduced during sample analysis from waterproofing sealants associated with the installation of a new rooftop air conditioner in KB Labs' mobile lab (KB2). The results from the piezometers validated the results obtained from the UltraSeep.

Results from the UltraSeep validation piezometer hydraulic conductivity, hydraulic gradient and specific discharge measurements are shown in Table 4-29. Validation of the UltraSeep flow measurements was conducted based on piezometers installed to a depth of 3 ft at three replicate locations adjacent to each UltraSeep station. A surface water stilling well was installed adjacent to each piezometer. The difference in level between the 3-ft piezometer and the stilling well was used to determine the vertical hydraulic gradient.

Falling head slug tests on each piezometer were used to determine the hydraulic conductivity. The specific discharge was then estimated based on the methods described in Section 4.4. Both sites (T3-3 and T4-4) showed a consistently positive vertical hydraulic gradient, with

average values ranging from 1.1 to 1.5 cm/m for T3-3 and 0.6 to 2.1 cm/m for T4-4. Hydraulic conductivity was generally somewhat higher at station T3-3, ranging from 293 to 389 cm/day compared to T4-4, which ranged from 74 to 273 cm/day. Estimated average specific discharge rates from the piezometers at T3-3 ranged from 3.5 to 4.9 cm/day compared to the average for the UltraSeep of 2.7 cm/day.

For station T4-4, the estimated average specific discharge rates from the piezometers ranged from 1.5 to 3.6 cm/day compared to the average for the UltraSeep of 5.0 cm/day. The fluctuating component of the discharge (mostly attributed to tides) had a similar magnitude for the piezometers and the UltraSeep, generally on the order of 1 to 2 cm/day. There appeared to be a phase difference in the tidal response of the piezometers compared to the UltraSeep, which may be attributable to piezometer response time relative to the tidal frequency. The piezometers generally showed reasonable agreement with the UltraSeep, given that the piezometer method is an indirect measure of specific discharge, and that there are likely to be spatial variations even on the small scales of separation that occurred during these deployments.

Table 4-26. VOC concentrations in UltraSeep discharge samples from station T4-4.

			UltraSeep T4-4									
			SM-T4-4-B1+ B2-A	SM-T4-4-B3-A/B	SM-T4-4-B4-A/B	SM-T4-4-B5-A/B	SM-T4-4-B5-A/B	SM-T4-4-B6-A/B	SM-T4-4-B7-A/B	SM-T4-4-B8-A/B	SM-T4-4-B9-A/B	SM-T4-4-B10-A/B
Field Replicate	MDL	PQL	1 8/17/04 Water	1 8/17/04 Water	1 8/17/04 Water	1 8/17/04 Water	2 8/17/04 Water	1 8/17/04 Water	1 8/17/04 Water	1 8/17/04 Water	1 8/17/04 Water	1 8/17/04 Water
Date of Analysis:												
Matrix:												
Dilution Factor:			1	1	1	1	1	1	1	1	1	1
1,1-Dichloroethene	0.5	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	0.3	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Trichloroethylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	0.1	1.0	1.0	0.7 I	< 1.0	0.7 I	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	0.8 I
Tetrachloroethylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
m,p-Xylene	0.4	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Naphthalene	2.4	5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0

All concentrations reported in µg/L.

Table 4-27. VOC concentrations in UltraSeep discharge samples from station T3-3.

			1 ft Piezometers					
			T4-4			T3-3R		
			PZ-T4-4-S1-A/B	PZ-T4-4-S2-A/B	PZ-T4-4-S3-A/B	PZ-T3-3R-S1-A/B	PZ-T3-3R-S2-A/B	PZ-T3-3R-S3-A/B
Field Replicate	MDL	PQL	1	1	1	1	1	1
Date of Analysis:			8/17/04	8/17/04	8/17/04	8/21/04	8/21/04	8/21/04
Matrix:			Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1
1,1-Dichloroethene	0.5	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	0.3	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Trichloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	0.1	1.0	< 1.0	< 1.0	< 1.0	3.7	3.1	4.3
Tetrachloroethene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	0.1	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
m,p-Xylene	0.4	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	0.2	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Naphthalene	2.4	5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0

Table 4-28. UltraSeep validation piezometer VOC results.

		Station T3-3				Station T4-4			
Field Replicate		A	B	C	Overall	A	B	C	Overall
Hydraulic Conductivity (cm/day)		293	354	389	346	273	170	74	172
Vertical Hydraulic Gradient (cm/m)	Average	1.5	1.1	1.2	1.2	1.5	0.6	2.1	1.4
	Min	0.9	0.3	0.8	0.7	0.6	-0.2	0.7	0.4
	Max	2.0	1.9	1.7	1.8	2.5	2.0	7.3	3.9
	Stdev	0.2	0.4	0.2	0.2	0.4	0.5	1.5	0.8
Piezometer Specific Discharge (cm/day)	Average	4.9	3.5	4.1	4.2	3.6	1.5	3.2	2.7
	Min	3.1	0.9	2.8	2.3	1.5	-0.4	1.1	0.7
	Max	6.6	6.2	5.6	6.2	6.0	4.8	11.0	7.3
	Stdev	0.6	1.2	0.5	0.8	0.9	1.2	2.3	1.5
UltraSeep Specific Discharge (cm/day)	Average				2.7				5.0
	Min				-0.7				0.4
	Max				6.1				10.1
	Stdev				1.5				2.0

All concentrations reported in µg/L.

Table 4-29. UltraSeep validation piezometer results for hydraulic conductivity, vertical hydraulic gradient, and specific discharge.

		Station T3-3				Station T4-4			
Field Replicate		A	B	C	Overall	A	B	C	Overall
Hydraulic Conductivity (cm/day)		293	354	389	346	273	170	74	172
Vertical Hydraulic Gradient (cm/m)	Average	1.5	1.1	1.2	1.2	1.5	0.6	2.1	1.4
	Min	0.9	0.3	0.8	0.7	0.6	-0.2	0.7	0.4
	Max	2.0	1.9	1.7	1.8	2.5	2.0	7.3	3.9
	Stdev	0.2	0.4	0.2	0.2	0.4	0.5	1.5	0.8
Piezometer Specific Discharge (cm/day)	Average	4.9	3.5	4.1	4.2	3.6	1.5	3.2	2.7
	Min	3.1	0.9	2.8	2.3	1.5	-0.4	1.1	0.7
	Max	6.6	6.2	5.6	6.2	6.0	4.8	11.0	7.3
	Stdev	0.6	1.2	0.5	0.8	0.9	1.2	2.3	1.5
UltraSeep Specific Discharge (cm/day)	Average				2.7				5.0
	Min				-0.7				0.4
	Max				6.1				10.1
	Stdev				1.5				2.0

UltraSeep specific discharge results are shown for comparison.



Figure 4-21. The UltraSeep being deployed in Saint Andrews Bay (bottom left and mid), installed on the bottom (bottom right), and viewed from above, including the array of VOC and level logging piezometers at station T4-4 (top).

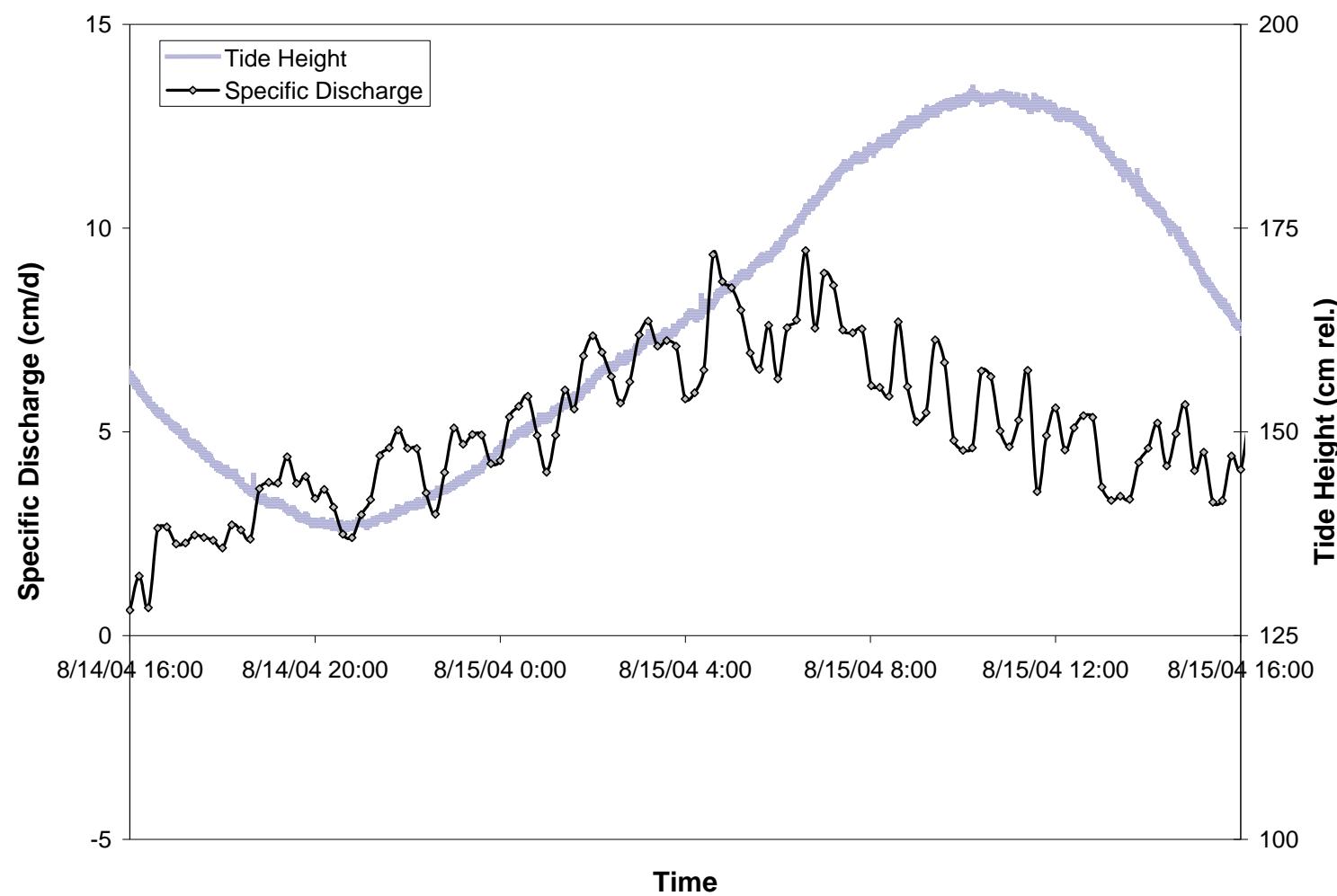


Figure 4-22. Specific discharge and tide height at the T4-4 station.

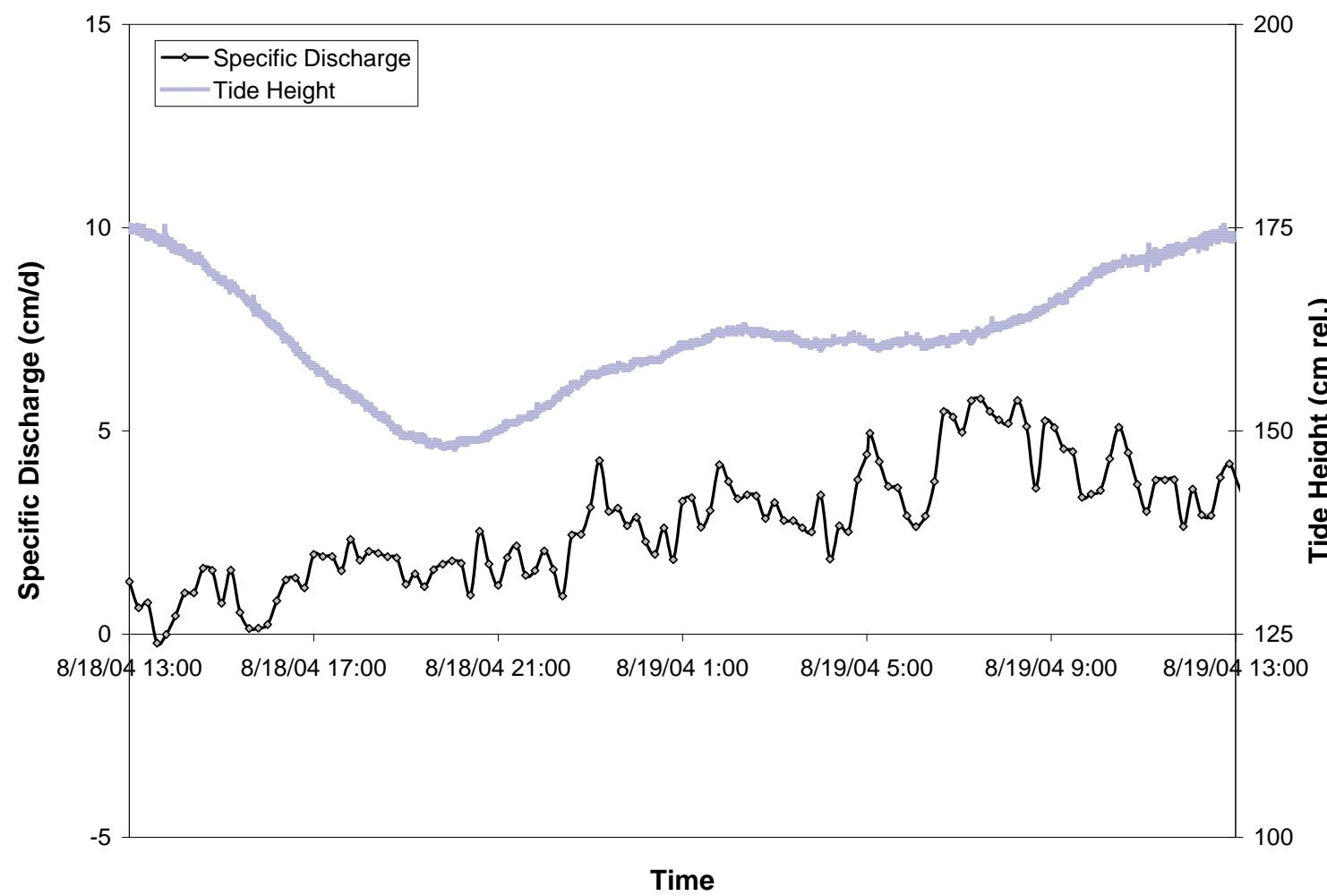


Figure 4-23. Specific discharge and tide height at the T3-3 station.

4.4.2 UltraSeep Survey Results—NTC Orlando

Results from the Trident probe sensor survey revealed potential groundwater discharge zones based on temperature contrast and the presence of sub-surface VOCs. Based on the results from the Trident probe survey, three stations extending offshore were selected for deployment of the UltraSeep (Figure 4-20). These stations included T3-7, T2-5, and T2-3. Station T3-7 was given the highest priority because it had the lowest Trident probe temperature measurement and elevated levels of TCE and DCE. Station T2-5 was given the second priority because it had a moderate Trident probe temperature signal that was clearly lower than the general background. This station also had elevated concentrations of PCE and TCE. Station T2-3 was given the third priority because it also had a moderate Trident probe temperature reading and elevated levels of DCE and VC.

UltraSeep deployments were used to quantify groundwater discharge rates, and VOC discharge concentrations and mass flux at the three target stations. All three UltraSeep station deployments were carried out successfully (Figure 4-24). Validation of the UltraSeep groundwater flow measurements was based on level-logging piezometers installed to a depth of 3 ft at three replicate locations adjacent to each UltraSeep station. Paired lake-level stilling wells were installed in conjunction with each piezometer (Figure 4-24). Validation of the UltraSeep VOC discharge measurements was conducted based on water sampling piezometers installed to a depth of 1 ft at three replicate locations adjacent to each UltraSeep station. UltraSeep and validation results are summarized in Subsections 4.4.2.1 through 4.4.2.3.

4.4.2.1 UltraSeep Groundwater Discharge

Groundwater discharge was quantified over a 24-hour period at each of the target stations. Ultrasonic flow data for the UltraSeep were processed to determine specific discharge rates. Raw data from the meter were recorded as a flow rate, generally in units of L/min. These flow data are converted to specific discharge based on the geometry of the flow tube and seepage funnel as

$$D = \frac{Q \left(\frac{L}{\text{min}} \right) \times 1000 \left(\frac{\text{cm}^3}{L} \right) \times 1440 \left(\frac{\text{min}}{\text{day}} \right)}{A_f \left(\text{cm}^2 \right)},$$

where Q is the flow rate measured by the ultrasonic flow meter, and A_f is the area of the funnel. The UltraSeep utilizes a round funnel with a diameter of 50 cm and an area of 1963 cm^2 . Specific discharge results for stations T3-7, T2-5, and T2-3 are shown in Figures 4-25 through 4-27. All three stations showed groundwater discharge.

UltraSeep Station T3-7. Station T3-7 was located near the shoreline with the vegetated zone on the eastern shore of Lake Druid. Station T3-7 seepage results are shown in Figure 4-25. The measurement period started at 1800 on 2 July 2005 and completed at 1800 on 3 July 2005. Seepage was always positive (discharge), with rates ranging from about 11 to 15 cm/day and a 24-hour mean discharge rate of 12.7 cm/day .

The discharge rate remained relatively constant throughout the deployment period, starting at about 15 cm/day and showing a very gradual decrease to about 11 cm/day at about 1300 on 3 July 2005, then increasing back to about 15 cm/day at 1500 on 3 July 7/3/05. The temporal standard deviation over the 24-hour period was about 0.9 cm/day . Station T3-7 had the highest groundwater discharge rate among the three stations. Lake level during the

deployment period was gradually increasing from about 3.5 ft (rel) to about 3.7 ft as a result of rainfall.

UltraSeep Station T2-5. Station T2-5 was located midway offshore along transect 2 at the outer extent of the vegetated zone on the eastern shore of Lake Druid. Seepage results for station T2-5 are shown in Figure 4-26. The measurement period started at 1500 on 4 July 2005 and completed at 1500 on 5 July 2005. Seepage was always positive (discharge) with rates ranging from about 1 to 4 cm/day and a 24-hour mean discharge rate of 2.4 cm/day.

The discharge rate remained relatively constant throughout the deployment period, with a temporal standard deviation over the 24-hour period of just 0.5 cm/day. Overall, ground-water discharge at this site was lower than the inshore station T3-7 by about a factor of five, and higher than the offshore station at T2-3 by about a factor of two. Lake level during the deployment period was fairly constant at about 5.5 ft (rel), with highest level of about 5.6 ft (rel) occurring at about 2200 on 4 July 2006.

UltraSeep Station T2-3. Station T2-3 was located near the offshore end along transect 2 off the eastern shore of Lake Druid. Seepage results for station T2-3 are shown in Figure 4-27. The measurement period started at 1500 on 6 July 2005 and completed at 1500 on 7 July 2005. Seepage was almost always positive (discharge) with rates ranging from about 0 to 2 cm/day and a 24-hour mean discharge rate of 1.1 cm/day. The discharge rate remained relatively constant throughout the deployment period, with a temporal standard deviation over the 24-hour period of just 0.6 cm/day. Overall, groundwater discharge at this site was the lowest of the three target stations. Lake level during the deployment period was fairly constant at about 11.75 ft (rel), with highest level of about 11.8 ft (rel) occurring at about 2300 on 6 July 2006.

4.4.2.2 UltraSeep Flow Validation Piezometers

TriPLICATE flow validation piezometers pairs were installed in a triangular array around the UltraSeep at each UltraSeep station. Each piezometer pair consisted of a sub-surface piezometer installed to a screen depth of 3 ft, and a surface water stilling well strapped directly to the side of the sub-surface piezometer. Water level was monitored in each of the triplicate piezometer pairs over the same 24-hour deployment period that the UltraSeep measurements were carried out. The difference in level between the sub-surface piezometer and the stilling well was then used to calculate the vertical hydraulic gradient. In addition, slug tests were carried out in each sub-surface piezometer to determine the hydraulic conductivity. Using the vertical hydraulic gradient and the hydraulic conductivity, seepage rates were estimated for each location in accordance with the procedures described in Section 4.

Results for the flow validation piezometers are summarized in Table 4-30. The average vertical hydraulic gradient generally decreased with distance from shore, ranging from a minimum of 1.4 cm/m at T2-3, to a maximum of 4.1 cm/m at T3-7. Hydraulic conductivity followed a similar trend, with a maximum average value of 351 cm/day at T3-7, and a minimum of 72 cm/day at T2-3. Station T2-5 had intermediate values of hydraulic gradient and conductivity.

Average specific discharge rates for the 24-hour period calculated from the piezometer gradients and hydraulic conductivity ranged from a minimum of 1.0 cm/day at T2-3 to a maximum of 14.3 cm/day at T3-7. These results were comparable to the average specific discharge rates measured directly by the UltraSeep (Table 4-30 and Figure 4-28). Direct comparison indicates that the piezometer and UltraSeep results were within about 10% at stations T2-3 and T3-7, but the difference at station T2-5 was somewhat higher (60%).

Variation among the replicate piezometers was significant at this station, which was possibly a result of its location on the fringe of the shoreline vegetated zone.

UltraSeep VOC discharge. At each target station, the UltraSeep collected flow-proportional water samples during periods of groundwater discharge from the sediment. The sampler was configured to collect samples over 10 intervals lasting 2.5 hours each. UltraSeep water samples are collected from a port in the funnel. Due to starting conditions, and variations in discharge and recharge, at any given time the funnel water may be a mixture of surface water and discharge water. For the concentration of discharge water to be determined, the discharge fraction must be determined. The volume of discharge water in the funnel for any given measurement time step is determined from a mass balance of the funnel as

$$V_d(i) = \begin{cases} V_d(i-1) + (Q_b(i) + Q_{f_t}(i)) \left(1 - \frac{V_d(i-1)}{V_f}\right) \Delta t & (\text{discharge}) \\ \max\left(0 \text{ and } V_d(i-1) - Q_{f_t}(i) \left(\frac{V_d(i-1)}{V_f}\right) \Delta t\right) & (\text{recharge}) \end{cases},$$

where V_d is the volume of discharge water in the funnel, Q_b is the flow rate to the sample bag, Q_{f_t} is the flow rate measured by the flow tube, V_f is the volume of the funnel (5.24 L for the UltraSeep), and Δt is the time step (always 1 minute). The discharge fraction for a sample is then given by

$$DF = \sum_{\text{sample}} V_d(i) Q_b(i) \Delta t,$$

where DF is the fraction of discharge water in a given sample. The discharge fraction for each UltraSeep sample, and for the composite of all 10 UltraSeep samples are given in Table 4-31.

Given the discharge fraction, the discharge concentration (c_D) can then be calculated as

$$c_D = c_s - c_o \left(\frac{1}{DF} - 1 \right),$$

where c_s is the concentration measured in the UltraSeep sample, and c_o is the starting concentration in the seepage funnel.

Raw sample results for the three UltraSeep stations are shown in 4-32 through 4-34. At station T3-7, sufficient discharge was present during samples 1 through 10 to conduct analysis for VOCs, including a replicate taken from sample 7. At station T2-5, sufficient discharge was also present during samples 1-10 to conduct analysis for VOCs. For station T2-3, sufficient discharge was present during samples 1 through 3 and samples 6 through 10 to conduct analysis for VOCs, with sample 3 as the replicate.

For samples 4 and 5, the individual sample volume was insufficient, so samples 4 and 5 were combined into one composite sample (SM-T2-3-[B4+B5]). At station T3-7, raw sample VOC concentrations above the PQL were detected for TCE, *cis*-DCE, and VC. Detectable levels of 1,1-Dichloroethene, *trans*-DCE, and toluene were also found at this station. VOC breakdown products were detected at station T2-5, including *cis*-DCE and VC, along with

toluene. Station T2-3 showed low levels of *cis*-DCE and VC. Toluene was not detected at this station.

To calculate the discharge concentration at each station, the concentration results from samples 8 through 10 were used when the discharge fraction was highest. This method minimizes uncertainty associated with the effects of the starting concentration. For the starting concentration, the concentration in the first sample was used, corrected for the estimated discharge fraction in that sample. This was achieved by iteratively solving for the discharge concentration, correcting the starting concentration, and then recalculating the discharge concentration until the change between subsequent iterations was <1%. The discharge fraction in the first sample ranged from a low of 2% (T2-3) to a high of 21% (T3-7).

Discharge concentrations were calculated for the primary VOCs of interest, including PCE, TCE, *cis*-DCE, and VC, subject to detection. Results are shown in Table 4-36 and Figure 4-29. At piezometer stations where some replicates were ND and some were not, one-half the detection limit was substituted for the NDs. If all replicates were ND, the results was listed as ND. If there was a detection by the UltraSeep, but not the piezometer, then the detection limit was listed for comparison's sake as an upper bound. If there were no detections in the UltraSeep raw samples, then the result was listed as ND unless there was a detection in the corresponding piezometer. In this case, the upper bound of the UltraSeep concentration was calculated by plugging in the detection limit to the discharge concentration calculation.

PCE was ND in the discharge water at any of the three target UltraSeep stations. Station T3-7 had the highest discharge concentrations for TCE, *cis*-DCE, and VC. TCE was ND in the discharge waters at stations T2-5 and T2-3, while these stations had comparable discharge concentrations for *cis*-DCE, and station T2-3 had a slightly higher VC concentration. Variability among replicate calculated discharge concentrations from the last three UltraSeep samples at each site was relatively low, with RSDs ranging from <1% to about 25%.

UltraSeep discharge concentrations were used in conjunction with UltraSeep measured discharge rates to quantify the mass flux of VOCs from groundwater to surface water at the three target stations. The mass flux is calculated as the integral over time of the product of discharge rate and concentration, divided by the sampling period. In this case, because the discharge rate is relatively constant, we calculated the mass flux as

$$M = \bar{D}c_D$$

where \bar{D} is the mean discharge rate. Mass flux for each of the target stations is summarized in Figure 4-. The combination of strong discharge rate and high discharge concentrations at station T3-7 lead to a dominant mass flux for VOCs at that station. VOC mass flux at stations T2-5 and T2-3 were comparable for *cis*-DCE and VC, and ND for TCE.

4.4.2.3 UltraSeep VOC Discharge Validation Piezometers

Results from the UltraSeep validation piezometer VOC samples are shown in Tables 4-35 and 4-37. The UltraSeep sampling validation was conducted based on piezometers installed to a depth of 1 ft at three replicate locations in a triangular pattern around each UltraSeep station. The piezometers were generally installed in triplicate within about 3 ft of the UltraSeep. The results indicate general agreement between these shallow piezometer samples and the discharge concentrations determined with the UltraSeep (Figure 4-29).

At station T2-3, PCE and TCE were both ND, while the mean cis-DCE and VC concentrations were somewhat lower in the UltraSeep discharge, but fell within the range of variability of the triplicate piezometers. PCE and TCE were ND in the UltraSeep discharge, with an estimated upper bound of <1.6 µg/L. This upper bound is consistent with the 0.7 µg/L concentration of PCE detected in the shallow piezometers (this mean included only one marginal detection), but is lower than the TCE concentration detected in the piezometers. Concentrations of cis-DCE and VC were comparable at this station.

At station T3-7, PCE was ND in the UltraSeep discharge and the piezometers. TCE and cis-DCE had comparable concentrations (within the range of variability). For VC, the discharge concentration was higher than for the piezometer, which was ND with an upper bound of <10 µg/L. Given that this bias was not observed at other stations, this finding suggests that VC may be forming as a degradation product from DCE very near the interface, or even in the surface water at this station.

Table 4-30. UltraSeep validation piezometer results for hydraulic conductivity, vertical hydraulic gradient, and specific discharge.

Station		T2-3				T2-5				T3-7			
Field Replicate		A	B	C	Overall	A	B	C	Overall	A	B	C	Overall
Hydraulic Conductivity (cm/day)		120	47	49	72	98	180	213	164	367	335	NA	351
Vertical Hydraulic Gradient (cm/m)	Average	1.3	0.7	2.1	1.4	2.7	2.6	4.9	3.4	4.4	3.7	NA	4.1
	Min	0.9	0.3	1.5	0.3	2.3	2.2	4.0	2.2	3.9	3.4	NA	3.4
	Max	1.8	1.4	3.0	3.0	3.1	3.1	5.4	5.4	4.8	4.0	NA	4.8
	StDev	0.2	0.2	0.3	0.7	0.1	0.2	0.2	1.3	0.2	0.1	NA	0.5
Piezometer Specific Discharge (cm/day)	Average	1.5	0.3	1.0	1.0	2.7	4.6	10.5	5.9	16.2	12.4	NA	14.3
	Min	1.0	0.2	0.7	0.2	2.3	3.9	8.5	2.3	14.4	11.4	NA	11.4
	Max	2.2	0.6	1.4	2.2	3.1	5.7	11.6	11.6	17.8	13.4	NA	17.8
	StDev	0.2	0.1	0.1	0.6	0.1	0.3	0.4	4.1	0.6	0.4	NA	2.7
UltraSeep Specific Discharge (cm/day)	Average	-	-	-	1.1	-	-	-	2.4	-	-	-	12.7
	Min	-	-	-	-0.5	-	-	-	1.4	-	-	-	10.8
	Max	-	-	-	2.4	-	-	-	3.6	-	-	-	14.9
	StDev	-	-	-	0.6	-	-	-	0.5	-	-	-	0.9

UltraSeep specific discharge results are shown for comparison.

Table 4-31. Calculated discharge fraction in each sample at each UltraSeep station.

Sample	Discharge Fraction		
	T2-3	T2-5	T3-7
1	2%	4%	21%
2	5%	11%	50%
3	8%	17%	69%
4	10%	22%	81%
5	12%	29%	88%
6	15%	35%	92%
7	17%	40%	95%
8	20%	43%	96%
9	22%	48%	98%
10	25%	51%	99%

Table 4-32. UltraSeep discharge VOC concentrations from station T3-7.

			UltraSeep Discharge T3-7										
			SM-T3-7-B1	SM-T3-7-B2	SM-T3-7-B3	SM-T3-7-B4	SM-T3-7-B5	SM-T3-7-B6	SM-T3-7-B7	SM-T3-7-B7	SM-T3-7-B8	SM-T3-7-B9	SM-T3-7-B10
Sampling Bag Replicate	MDL	PQL	1	1	1	1	1	1	1	2	1	1	1
Date of Analysis:			7/5/05	7/5/05	7/5/05	7/5/05	7/5/05	7/5/05	7/5/05	7/5/05	7/5/05	7/5/05	7/5/05
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1,10	1,10	1,10	1,10	1,10	1,10	10	1,10	10	10	10
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
Vinyl Chloride (VC)	<1.0	1	47.6	50	49	49.1	51.1	52.7	47	50.1	48	50	50
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
1,1-Dichloroethene	<1.0	1	<1.0	1.3	1.4	1.4	1.5	1.5	<10	1.5	<10	<10	<10
trans -DCE	<1.0	1	3	3	3	2.8	3.1	3.2	<10	3	<10	<10	<10
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
2,2-Dichloropropane	<1.0	1	1	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
cis -DCE	<1.0	1	430	510	440	440	440	450	470	500	500	510	510
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
Trichloroethene (TCE)	<1.0	1	3.2	3.9	4	4.3	4.5	4.8	<10	4.5	<10	<10	<10
cis -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
Toluene	<1.0	1	3.6	4.4	4	3.6	3.3	3.2	<10	3	<10	<10	<10
trans -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<10	<10	<10

All concentrations are reported in $\mu\text{g/L}$.

Table 4-33. UltraSeep discharge VOC concentrations from station T2-5.

			UltraSeep Discharge T2-5										
			SM-T2-5-B1	SM-T2-5-B2	SM-T2-5-B3	SM-T2-5-B4	SM-T2-5-B5	SM-T2-5-B6	SM-T2-5-B6	SM-T2-5-B7	SM-T2-5-B8	SM-T2-5-B9	SM-T2-5-B10
Units for water: ug/L.													
Sampling Bag Replicate	MDL	PQL	1	1	1	1	1	1	2	1	1	1	1
Date of Analysis:			7/6/05	7/6/05	7/7/05	7/7/05	7/6/05	7/6/05	7/6/05	7/7/05	7/7/05	7/7/05	7/6/05
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1	1	1	1	1
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	1	<1.0	<1.0	<1.0	1.4	1.2	1.1
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
trans-DCE	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
cis-DCE	<1.0	1	7.2	6.7	5.7	5.5	7.4	6.4	7	6.7	8.9	8.1	10.2
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethylene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
cis-1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1	1.2
trans-1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethylene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations are reported in $\mu\text{g}/\text{L}$.

Table 4-34. UltraSeep discharge VOC concentrations from station T2-3.

			UltraSeep Discharge T2-3									
			SM-T2-3-B1	SM-T2-3-B2	SM-T2-3-B3	SM-T2-3-B3	SM-T2-3-B4+B5	SM-T2-3-B6	SM-T2-3-B7	SM-T2-3-B8	SM-T2-3-B9	SM-T2-3-B10
Units for water: ug/L.												
Sampling Bag Replicate	MDL	PQL	1	1	1	2	1	1	1	1	1	1
Date of Analysis:			7/8/05	7/8/05	7/8/05	7/8/05	7/8/05	7/8/05	7/8/05	7/8/05	7/8/05	7/8/05
Matrix:			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Dilution Factor:			1	1	1	1	1	1	1	1	1	1
Dichlorodifluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1	1.3	1
Trichlorofluoromethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -DCE	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -DCE	<1.0	1	1.8	2	1.6	1.4	1.4	3.2	2.8	3.2	3.9	3.3
1,1,1-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations are reported in $\mu\text{g}/\text{L}$.

Table 4-35. UltraSeep validation piezometer VOC results.

Units for water: ug/L.			1 ft Piezometers									
			T3-7			T2-5			T2-3			
			PZ-T3-7	PZ-T3-7	PZ-T3-7	PZ-T2-5	PZ-T2-5	PZ-T2-5	PZ-T2-3	PZ-T2-3	PZ-T2-3	PZ-T2-3
			A	B	C	A	B	C	A	B	C	
Field Replicate	MDL	PQL	7/6/05	7/6/05	7/6/05	7/7/05	7/7/05	7/7/05	7/7/05	7/7/05	7/7/05	
Date of Analysis:			Water	Water	Water	Water	Water	Water	Water	Water	Water	
Matrix:			10	10	10	1	1	1	1	1,10	1	
Dilution Factor:												
Dichlorodifluoromethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride (VC)	<1.0	1	<10	<10	<10	4.2	3.1	1.9	40.3	<1.0	20.2	
Trichlorofluoromethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -DCE	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2,2-Dichloropropane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -DCE	<1.0	1	490	240	270	13.3	11.8	25.7	55.4	120	13.1	
Chloroform	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene (TCE)	<1.0	1	<10	11	<10	<1.0	15.5	1.3	<1.0	<1.0	<1.0	<1.0
1,2-Dichloropropane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>cis</i> -1,3-Dichloropropene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>trans</i> -1,3-Dichloropropene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene (PCE)	<1.0	1	<10	<10	<10	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0
Dibromochlormethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dibromoethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>m,p</i> -Xylene	<1.0	2	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<i>o</i> -Xylene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Styrene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Isopropylbenzene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromobenzene	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<5.0	1	<50	<50	<50	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	<1.0	1	<10	<10	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

All concentrations are reported in $\mu\text{g/L}$.

Table 4-36. Individual and mean validation piezometer VOC concentrations, and calculated VOC discharge concentrations based on samples 8 through 10 and their mean for UltraSeep.

Device	Sub-sample	T2-3				T2-5				T3-7			
		PCE	TCE	cis-DCE	VC	PCE	TCE	cis-DCE	VC	PCE	TCE	cis-DCE	VC
Piezometer	A	<1	<1	55	40	<1	<1	13	4.2	<10	<10	490	<10
	B	<1	<1	120	<1	1.0	16	12	3.1	<10	11	240	<10
	C	<1	<1	13	20	<1	1.3	26	1.9	<10	<10	270	<10
	Mean	NA	NA	63	20 ^a	0.7 ^a	5.8 ^a	17	3.1	NA	7.0 ^a	333	<10 ^b
	Stdev	NA	NA	54	20	0.3	8.4	7.6	1.2	NA	3.5	137	NA
UltraSeep	Sample 8	ND	ND	13	7.1	ND	ND	14	3.2	ND	5.1	503	48
	Sample 9	ND	ND	18	9.3	ND	ND	11	2.5	ND	5.1	512	50
	Sample 10	ND	ND	14	7.1	ND	ND	18	2.2	ND	5.0	512	50
	Mean	NA	NA	15	7.8	<1.6 ^c	<1.6 ^c	14	2.6	NA	5.1	509	49
	Stdev	NA	NA	2.7	1.2	NA	NA	3.6	0.5	NA	0.0	5.0	1.2

^aMean calculated using one-half the detection limit for non-detects

^bMean assumed less than detection limit for comparison to UltraSeep

^cMean calculated as upper bound of possible UltraSeep discharge concentration



Figure 4-24. Field deployment and UltraSeep validation at three locations along Lake Druid.

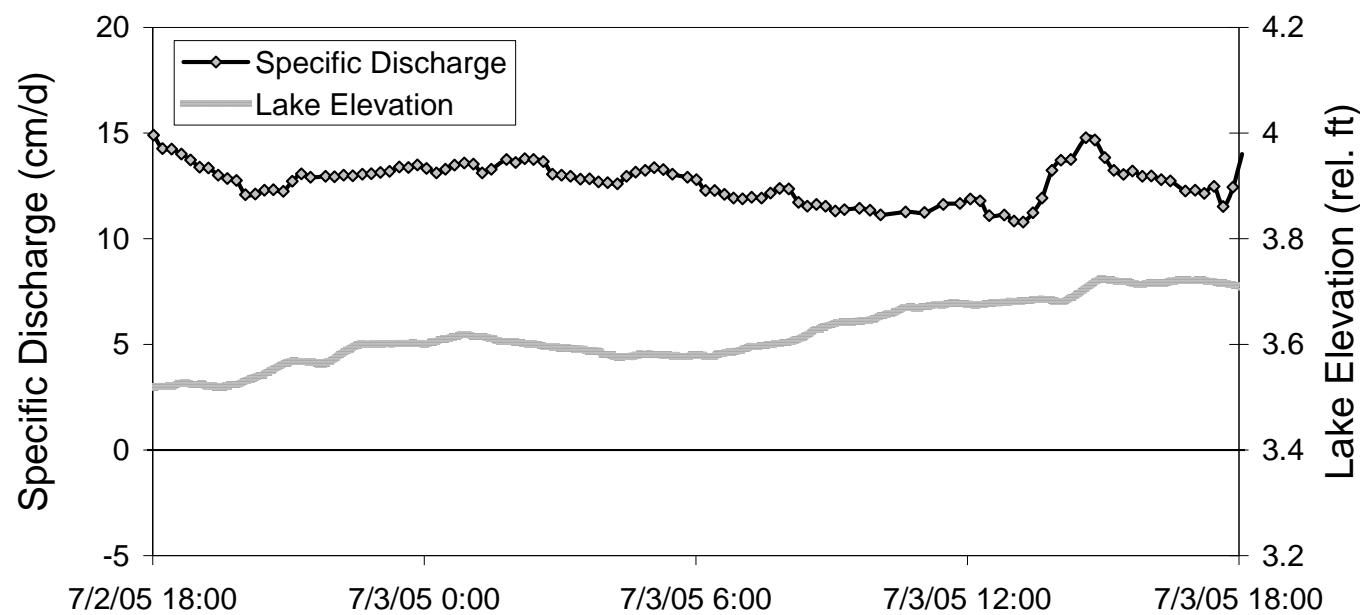


Figure 4-25. Specific discharge and lake level at the T3-7 station.

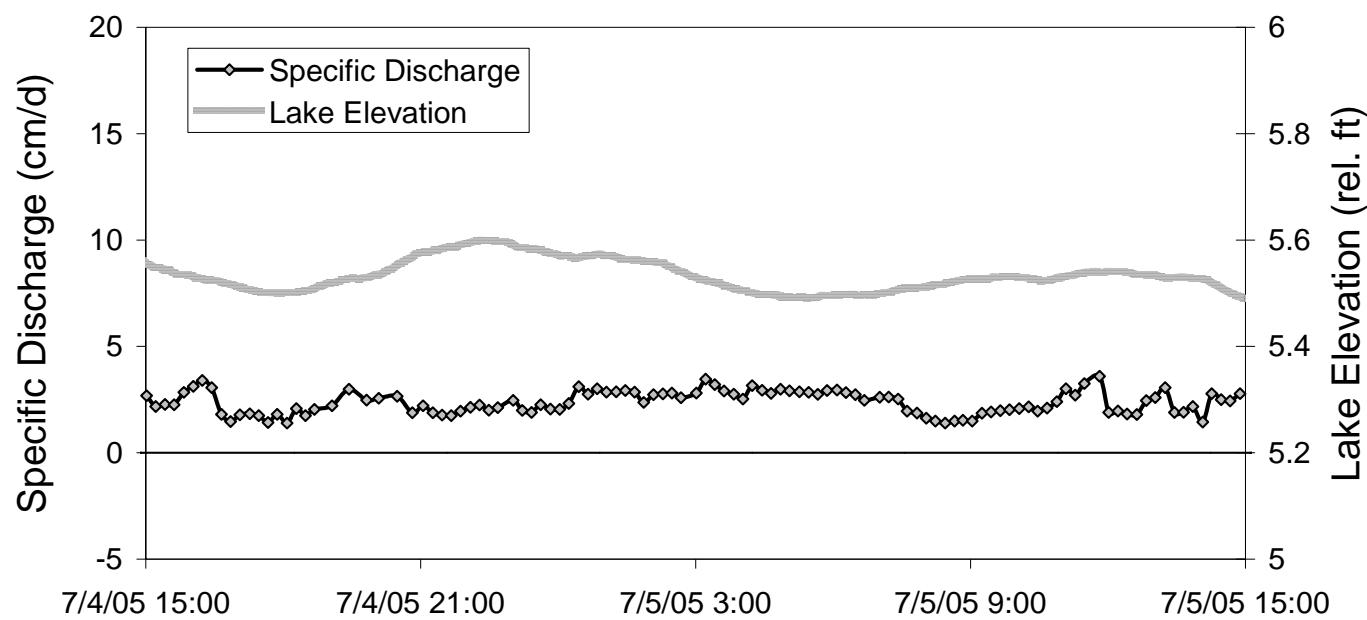


Figure 4-26. Specific discharge and lake level at T2-5 station.

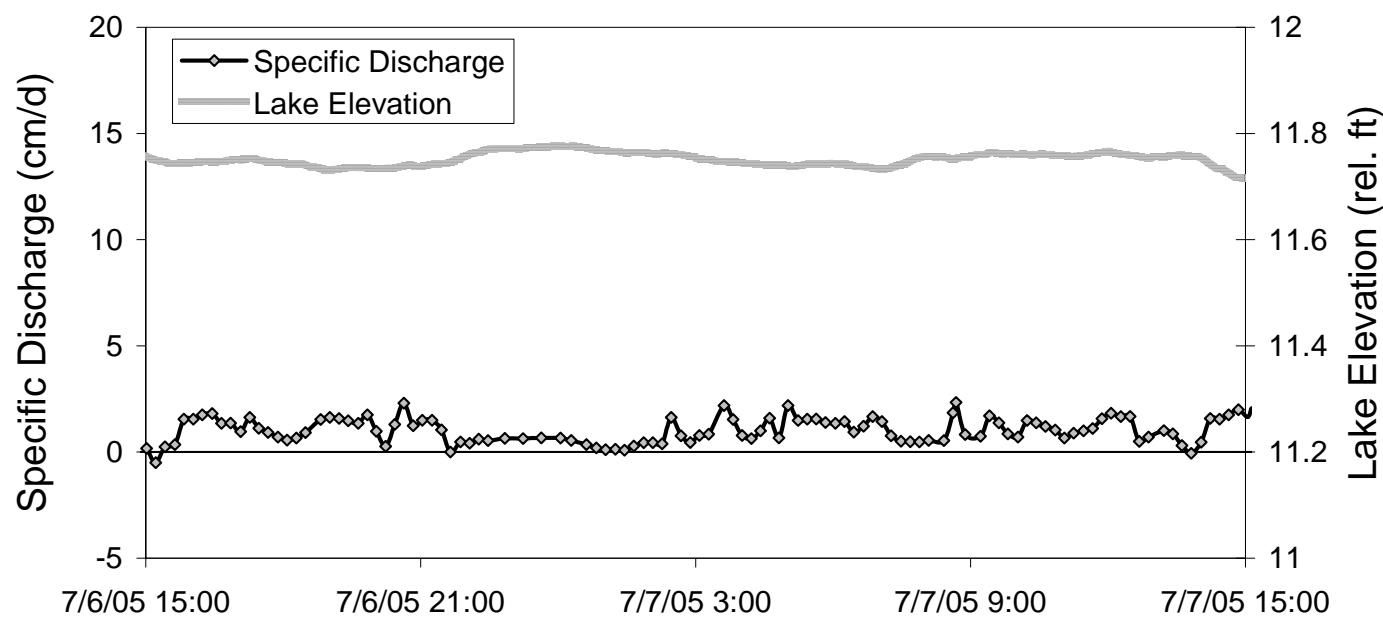


Figure 4-27. Specific discharge and lake level at T2-3 station.

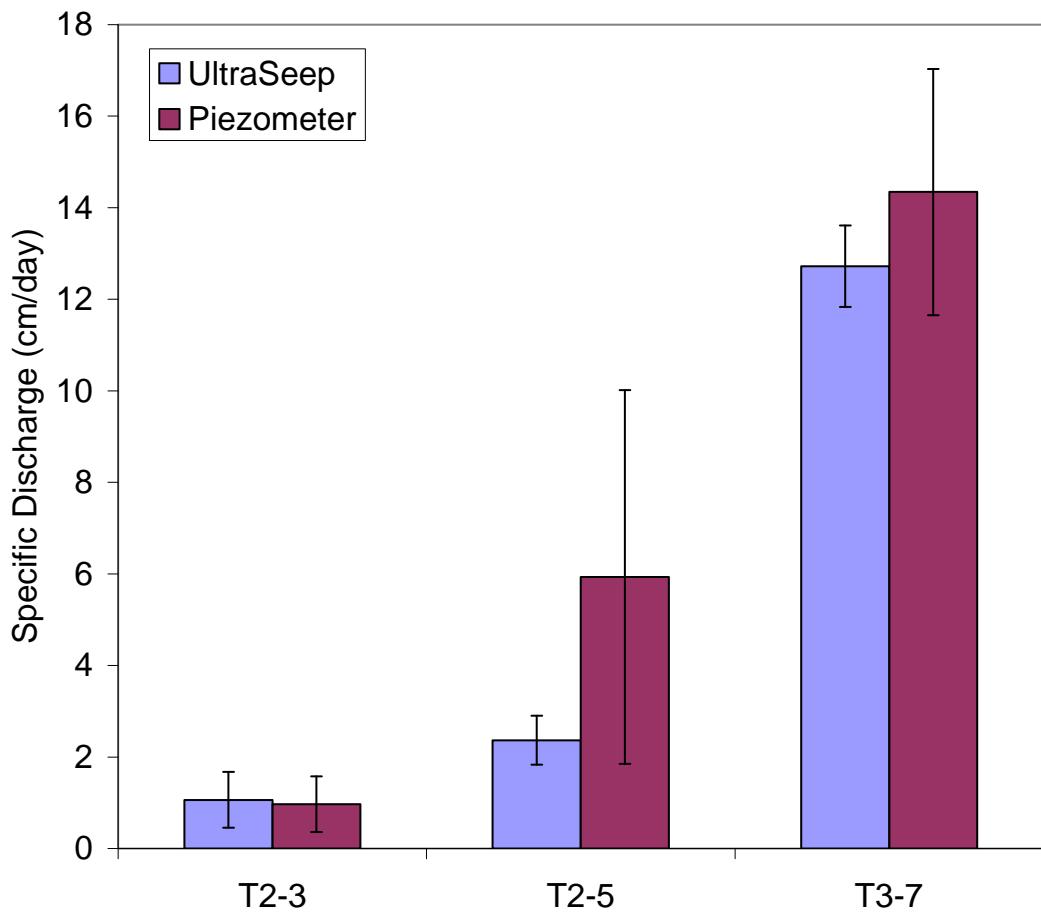


Figure 4-28. UltraSeep flow validation at each station.

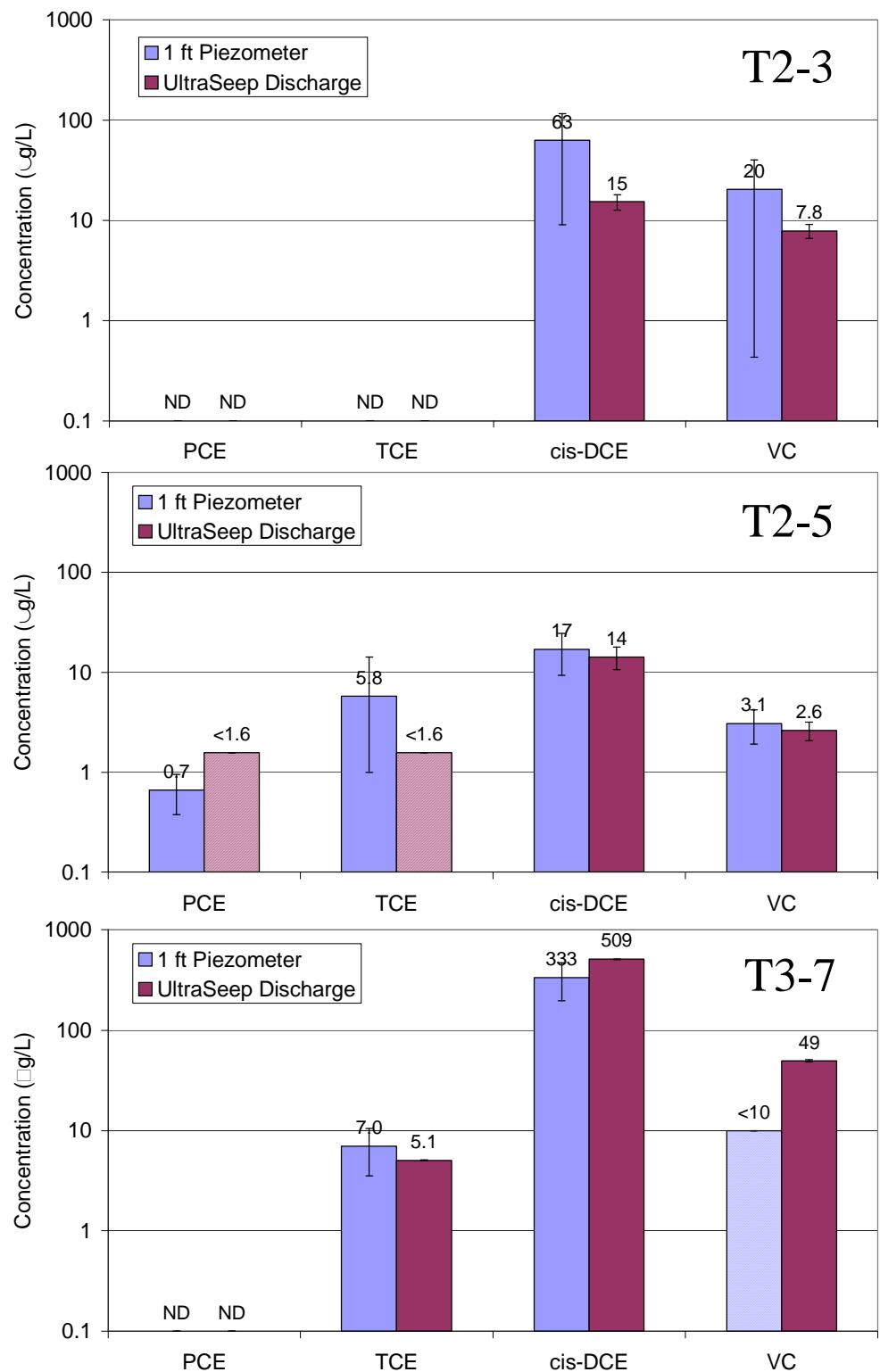


Figure 4-29. UltraSeep VOC validation at each station.

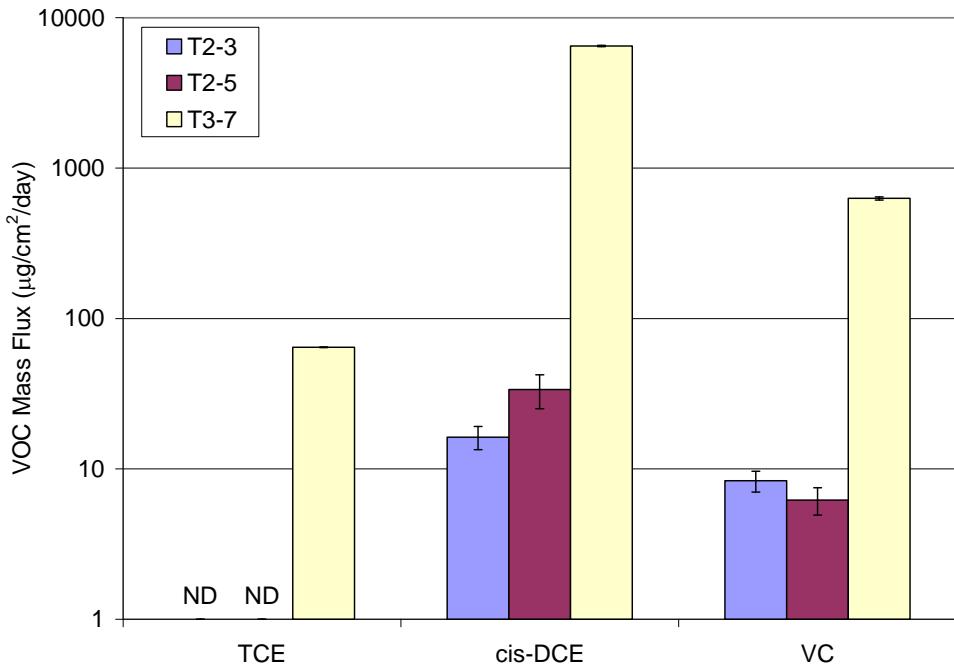


Figure 4-30. VOC mass flux at UltraSeep stations.

4.5 DEMONSTRATION SUMMARY

4.5.1 NSA Panama City

A coastal contaminant migration monitoring assessment was conducted at NSA Panama City. The objective of the project was to field demonstrate and evaluate the effectiveness of the Trident probe and UltraSeep for characterizing coastal contaminant migration. The results of the demonstration were used to evaluate the validity of monitored natural attenuation as a corrective action alternative for AOC1 at NSA Panama City.

The Trident probe was used successfully to identify groundwater discharge areas from the site to the surface waters of Saint Andrew Bay. Thirty offshore stations were sampled with the probe sensors and water sampler. The zone of discharge appeared to be limited to a band extending parallel to shore between about 100 to 300 ft offshore. All VOC analytes, including DCE at all Trident probe stations, were below the PQL. No detectable DCE or other VOCs were measured in the sub-surface or surface water in the groundwater discharge areas identified with the Trident probe sensors. The results from shallow (2 ft) piezometers installed on transect T3 validated the Trident probe results.

The UltraSeep was used successfully to quantify groundwater discharge rates and VOC discharge concentrations in two discharge zones identified with the Trident probe. At station T4-4, groundwater discharge was always positive, with rates ranging from about 2 to 8 cm/d, and a 24-hour mean discharge rate of 5.1 cm/d. At station T3-3, groundwater discharge was always positive with rates ranging from about 1 to 5 cm/d and a 24-hour mean discharge rate of 2.7 cm/d. The positive discharge at these locations was consistent with the results from the Trident probe survey.

Although groundwater discharge was detected at both stations, all VOC analytes, including DCE in all UltraSeep samples, were below the PQL with the exception of toluene. The source of the low level toluene in these samples may have originated from the sampling system on the UltraSeep (T4-4 samples), or may have originated from vapors released by roofing sealants at KB Labs during the analysis (T3-3 samples). Results from three shallow piezometers installed adjacent to each UltraSeep station validated the results obtained from the UltraSeep.

Overall, the project was successful in demonstrating the utility of the Trident probe and UltraSeep in assessing coastal contaminant migration. No DCE discharge into St. Andrews Bay at levels above the SWCTL of 3.2 µg/L was detected. Thus, the results from the study support the selection of monitored natural attenuation as a corrective action alternative for the site.

4.5.2 NTC Orlando

The overall objective of this project was to field demonstrate and evaluate the effectiveness of two technologies for characterizing coastal contaminant migration. The technologies include recently commercialized versions of a screening probe for determining where groundwater may be discharging (Trident probe), and an integrated seepage meter and water sampling system for quantifying discharge rates and chemical loading (UltraSeep System). The demonstration represented a full-scale technology evaluation in the field using the Trident probe and the UltraSeep. The technologies were demonstrated in an offshore area adjacent to a known hazardous waste site where there is documented evidence of potential contaminant migration to the surface water.

The field demonstration was performed at the former NTC Orlando, Orlando, Florida. The primary contaminant of concern at OU 4 NTC Orlando was PCE and its degradation products, which have been detected at concentrations exceeding the surface water cleanup target level along the Lake Druid shoreline. An extraction and treatment system had been installed; however, it was unclear whether VOCs were continuing to enter the lake and at what rate. The stated objectives of this field effort were as follows:

- Demonstrate that the Trident probe can be used to help identify areas where groundwater seepage is occurring in a freshwater lake environment, and to map the lateral extent of any sub-surface contamination at the groundwater–surface water interface.
- Demonstrate that the UltraSeep system can be used to quantify the flow of groundwater and concentration of contaminants that may be impinging on the surface water system.
- Demonstrate the technology to end-users to determine the utility of these tools for making decisions at DoD coastal landfills and hazardous waste sites.
- Quantify costs associated with the operation of each of the technologies.

The Trident probe was used successfully to identify areas of groundwater discharge from the site to the surface waters of Lake Druid. Thirty-one offshore stations were sampled with the probe sensors and water sampler. Two zones of potential groundwater discharge were successfully identified. One near-shore band appeared to be extending parallel to the shoreline about 50 to 100 ft offshore. Another zone which was previously unknown extends 200 to 300 ft offshore. Most of the VOC analytes detected at the Trident probe stations were above the PQL. Detectable levels of PCE, TCE, DCE, VC and/or other VOCs were measured

in either the sub-surface or surface water in the groundwater discharge areas identified with Trident probe sensors. The results from shallow (2 ft) piezometers installed on transect T3 validated the Trident probe results.

The UltraSeep was successfully deployed to quantify groundwater discharge rates and VOC discharge concentrations in two discharge zones identified with Trident probe screening. The strongest discharge was in the near-shore discharge zone at station T3-7. The groundwater discharge was always positive, with rates ranging from about 12 to 16 cm/day, and a 24-hour mean discharge rate of 12.7 cm/day. At station T2-5, groundwater discharge was always positive, with rates ranging from about 2 to 4 cm/day and a 24-hour mean discharge rate of 2.4 cm/day. The weakest discharge was measured offshore at station T2-3. The groundwater discharge at this site was always positive, with rates ranging from about 0 to 3 cm/day and a 24-hour mean discharge of 1.1 cm/day. The positive discharge at these locations was consistent with the Trident probe survey results.

Discharge concentrations were calculated for the primary VOCs of interest, including PCE, TCE, *cis*-DCE, and VC, subject to detection. PCE was not detected in the discharge water at any of the three target UltraSeep stations. Station T3-7 had the highest discharge concentrations for TCE, *cis*-DCE, and VC. TCE was ND in the discharge waters at stations T2-5 and T2-3, while these stations had comparable discharge concentrations for *cis*-DCE, and station T2-3 had a slightly higher VC concentration. Variability among replicate calculated discharge concentrations from the last three UltraSeep samples at each site was relatively low, with RSDs ranging from <1% to about 25%.

UltraSeep discharge concentrations were used in conjunction with UltraSeep measured discharge rates to quantify the mass flux of VOCs from groundwater to surface water at the three target stations. The combination of strong discharge rate and high discharge concentrations at station T3-7 lead to a dominant mass flux for VOCs at that station. VOC mass flux at stations T2-5 and T2-3 were comparable for *cis*-DCE and VC, and ND for TCE.

The UltraSeep sampling validation was based on piezometers installed to a depth of 1 ft at three replicate locations in a triangular pattern around each UltraSeep station. The results indicate general agreement between these shallow piezometer samples and the discharge concentrations determined with the UltraSeep.

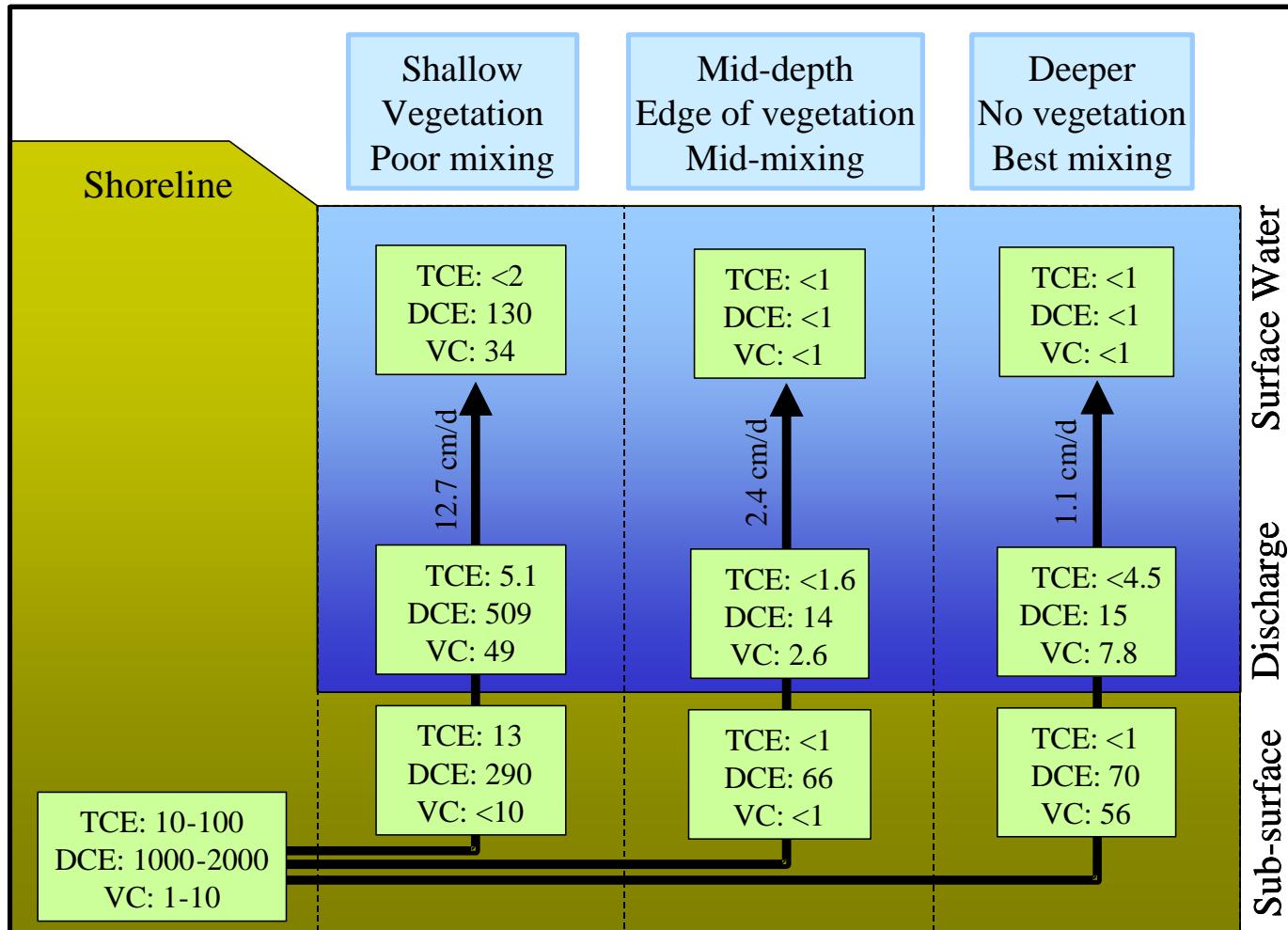
At station T2-3, PCE and TCE were both non-detect, while the mean *cis*-DCE and VC concentrations were somewhat lower in the UltraSeep discharge, but fell within the range of variability of the triplicate piezometers. PCE and TCE were ND in the UltraSeep discharge, with an estimated upper bound of <1.6 µg/L. This upper bound is consistent with the 0.7-µg/L concentration of PCE detected in the shallow piezometers, but is lower than the TCE concentration detected in the piezometers. Concentrations of *cis*-DCE and VC were comparable at this station.

At station T3-7, PCE was ND in both the UltraSeep discharge and the piezometers. TCE and *cis*-DCE had comparable concentrations (within the range of variability). For VC, the discharge concentration was higher than for the piezometer, which was ND with an upper bound of <10 µg/L. Given that this bias was not observed at other stations, this finding suggests that VC may be forming as a degradation product from DCE very near the interface or even in the surface water at this station.

Overall results for the demonstration are summarized schematically in Figure 4-31. In the schematic, shoreline concentrations are based on the range reported in shoreline monitoring wells and piezometers, offshore subsurface concentrations are based on the Trident probe

samples, offshore discharge concentrations are based on the UltraSeep measurements, and offshore surface water concentrations are based on the surface water samples collected with Trident probe (Shallow = Station T3-7; Mid-Depth = Station T2-5; Deeper = Station T2-3).

The results show how discharge of VOCs to the lake are regulated by the physical pathway and the chemical attenuation that occurs along these pathways, along with the effects of localized mixing in the lake itself. From the schematic, it is clear that areas close to shore have the strongest discharge and the least attenuation of VOCs, while the areas further from shore tend to have lower discharge rates and higher attenuation. Near the shore, the shallow water and low mixing, coupled with the higher discharge rates, leads to higher concentrations in the surface water of the lake, while further offshore the lower discharge and better mixing generally leads to undetectable VOC concentrations in the surface water. Overall, the project was successful in demonstrating the utility of the Trident probe and UltraSeep in assessing coastal contaminant migration.



All concentrations reported in $\mu\text{g/L}$.

Figure 4-31. Schematic of Trident probe and UltraSeep demonstration results at NTC Orlando OU 4.

5. COST ASSESSMENT

5.1 COST REPORTING

Cost issues are critical to the evaluation and acceptance of innovative technologies. Along with demonstrating and validating the Trident probe and UltraSeep technologies, an important goal of this project was to develop and validate, to the extent possible, the expected operational costs of the technologies. Relevant costs and related data described in this section were tracked and documented during the demonstration so that the operational costs of the technology can be estimated with a high degree of veracity.

During the course of the project, commercialization has proceeded in partnership with two commercialization partners. The Oceanscience Group has completed commercialization of the hardware systems, and Groundwater Seepage Incorporated has developed a commercial services capability. The costs summarized discussed below are largely based on data provided by these commercial entities through their experience on the demonstration projects and a number of additional efforts during the demonstration project.

5.2 COST ANALYSIS

5.2.1 Cost Comparison

Baseline alternatives for cost comparison purposes are listed below for each of the technologies. However, the Trident probe and UltraSeep represent new technologies that provide capabilities that are not achievable by existing technologies, including these baseline technologies. The baseline technologies may be difficult to install at sites with active shipping, whereas the Trident probe and UltraSeep are amenable to these settings.

In addition to direct comparison to other technologies, the demonstrations, particularly at NSA Panama City, indicated how the technologies may lead to significant cost avoidance if they provide sufficiently reliable and convincing technical support to select MNA as a final remedy or corrective action instead of a more costly active remedial option.

As indicated by the project team at NAS Panama City: “Without direct measurements at the groundwater / surface water interface, the assumed concentration of 1,1-DCE in discharge to surface water would have been based on the monitoring wells closest to St. Andrews Bay. Since the well concentrations exceeded the FDEP Surface Water Cleanup Target Levels, a containment system or barrier would have been required. This project allowed the Navy to avoid an estimated \$1,250,000 that had been previously budgeted for construction of a barrier.”

5.2.1.1 Trident Probe Baseline Technology Comparison

Micro-well network

5.2.1.2 UltraSeep Baseline Technology Comparison

Piezometer networks

Lee meters

The cost analysis for the Trident probe and UltraSeep technologies relative to the baseline technologies are summarized in Table 5-2. Based on typical site parameters, the cost of an integrated Trident probe/UltraSeep survey is expected to be on the order of \$120K. This represents a cost savings of about 42% relative to the estimated cost for the baseline technology of about \$210K. Much of the cost difference stems from the higher labor load

associated with installing enough micro wells to provide comparable spatial resolution to the Trident probe system. Additional labor load is also associated with the labor-intensive nature of the Lee Meters when trying to provide time-resolved seepage measurements and discharge samples as is critical in tidally influenced coastal environments.

5.2.2 Cost Basis

The cost basis (e.g., scale of operation) that was used for the future cost analysis was based on an estimated site scale developed from the ESTCP demonstration sites, Y0817 test sites, and other sites that are currently under investigation or considering investigation. The cost basis for the Trident probe and UltraSeep technologies is primarily controlled by the spatial scale of the site and the number of stations and samples that must be generated to adequately satisfy the data quality objectives. The typical site scale and design parameters that was used for the cost analysis is summarized in Table 5-1.

5.2.3 Cost Drivers

The expected cost drivers for the Trident probe and UltraSeep technologies are largely driven by labor, analytical laboratory, supplies, transportation, and capital equipment costs associated with planning, mobilization, operation, demobilization, data analysis, and reporting. Capital costs for the Trident probe and UltraSeep technologies have been developed by the manufacturer, Oceanscience Group. Purchase, lease, and service cost options are available as the company develops the technology.

For purchase of the equipment, it is expected that capital costs would be amortized over a fairly large number of site evaluations before the purchase of new equipment would be required, and that these costs would be recouped through equipment fees passed on to the customer. Estimated costs for other ancillary capital equipment was documented during the demonstrations. Most of the future engineering, modifications, and upgrades to the equipment are expected to be capitalized by the manufacturer and recouped in the purchase, lease, or service cost for the technology.

Operating costs for the technologies are largely controlled by the labor rates and number of personnel required to field the equipment, analyze the data, and generate the documentation associated with the project. These factors were carefully documented during the demonstrations. Other operating costs include analytical costs, consumables, residuals handling, and system maintenance. Most maintenance functions can be carried out by the operating team.

Mobilization and demobilization costs are largely related to labor and shipping cost. Shipping costs can vary considerably, depending on the distance to the site and the shipment method. Labor costs for mobilization and demobilization should be relatively constant. Mobilization and demobilization costs were documented as part of the demonstration.

5.2.4 Life-Cycle Costs

Estimates of life-cycle costs for the technology were based on the expected working life of the systems (5 to 10 years). Capital cost estimates provided by the manufacturer, along with estimated capital costs for ancillary equipment, were used to develop a life-cycle cost for the technology in collaboration with GSI. The cost analysis incorporates these costs via equipment fees that are passed on to the customer (Table 5-3). The current rates indicate that the capital investment for the Trident probe and UltraSeep, including ancillary equipment, could be recouped within the expected 5- to 10-year working life, with ~30 uses/year, which is well within the expected market demand for the technology.

Table 5-1. Site scale and design parameters used for cost analysis.

Parameter	Scale or Design Element
Study Driver	Terrestrial groundwater-borne solvent plume migrating toward adjacent surface water body
Survey Area	500 ft alongshore X 200 ft offshore
Trident Sensor Grid	60 stations @ 50 ft alongshore X 50 ft offshore plus 5 contingency and replicates
Trident Porewater Sampling	15 stations based on sensor results
UltraSeep Sampling	5 stations based on Trident sensor and porewater results

Table 5-2. Cost analysis for Trident probe and UltraSeep technologies compared to baseline technologies.

Cost Category	Sub Category	Trident/UltraSeep				Baseline Technology				Details
		Rate	Units	Days	Cost	Rate	Units	Days	Cost	
Labor Costs										
Planning	Preliminary study design	1000	1	2	2000	1000	1	2	2000	Principal 2 days
	Preliminary budget	1000	1	2	2000	1000	1	2	2000	Principal 2 days
	Final budget	1000	1	3	3000	1000	1	3	3000	Principal 3 days
	Contract Agreement	1000	1	3	3000	1000	1	3	3000	Principal 3 days
	Sampling Plan	1000	1	5	5000	1000	1	5	5000	Principal 5 days
	Material Orders	600	1	3	1800	600	1	3	1800	Technician 3 days
	Sub-total				16800				16800	
Mobilization Costs	Equipment checkout	600	1	1	600	600	1	1	600	Technician 1 day
	Calibration	600	1	3	1800	600	1	3	1800	Technician 3 days
	Pre-clean	600	1	2	1200	600	1	2	1200	Technician 2 days
	Packing	600	1	2	1200	600	1	2	1200	Technician 2 days
	Shipping	600	1	2	1200	600	1	2	1200	Technician 2 days
	Sub-total				6000				6000	
Operating Costs	On-site setup/testing	1000	1	1	1000	1000	1	3	3000	T/U: 1 PI & 2 Tech @ 1 day
		600	2	1	1200	600	2	3	3600	BT: 1 PI & 2 Tech @ 3 days
	Grid survey and marking	1000	1	1	1000	1000	1	1	1000	T/U: 1 PI & 2 Tech @ 1 day
		600	2	1	1200	600	2	1	1200	BT: 1 PI & 2 Tech @ 1 day
	Micro well installation				1000		1	6	6000	60 stations @ 8-10 stations/day
					600		5	6	18000	BT: 1 PI & 5 Tech @ 6 days
	Trident C/T sensor survey	1000	1	3	3000					60 stations @ 20-25 stations/day
		600	2	3	3600					T/U: 1 PI & 2 Tech @ 3 days
	Micro well C/T sampling				1000		1	5	5000	60 stations @ 10-12 stations/day
					600		5	5	15000	BT: 1 PI & 5 Tech @ 5 days
	Porewater CoC sampling	1000	1	3	3000					15 stations @ 5 stations/day
		600	2	3	3600					T/U: 1 PI & 2 Tech @ 3 days
	Level logging PZ install				1000		1	2	2000	5 stations + stilling well
					600		2	2	2400	BT: 1 PI & 2 Tech @ 2 days
	UltraSeep Sampling	1000	1	4	4000					5 stations @ 3 stations/day
		600	2	4	4800					T/U: 1 PI & 2 Tech @ 4 days
	Lee Meter Sampling	1000	1		1000		1	4	4000	5 stations @ 5 stations/ 2 days
		600	2		600		5	4	12000	BT: 1 PI & 5 Tech @ 2 days
	Sample handling and shipping	600	1	2	1200	600	1	2	1200	1 Tech @ 2 days
	Sub-total				27600				74400	

Table 5-2. Cost analysis for Trident probe and UltraSeep technologies compared to baseline technologies. (continued)

Cost Category	Sub Category	Trident/UltraSeep				Baseline Technology				Details
Labor Costs		Rate	Units	Days	Cost	Rate	Units	Days	Cost	
Demobilization Costs	Demob micro wells					1000	1	2	2000	BT: 1 PI & 2 Tech @ 2 days
					600	1	2	1200		
	Post-clean	1000	1	0.5	500	1000	1	0.5	500	1 PI & 1 Tech @ 0.5 days
		600	1	0.5	300	600	1	0.5	300	
	Packing	1000	1	1	1000	1000	1	1	1000	1 PI & 1 Tech @ 1 day
		600	1	1	600	600	1	1	600	
	Shipping	1000	1	0.5	500	1000	1	0.5	500	1 PI & 1 Tech @ 0.5 days
		600	1	0.5	300	600	1	0.5	300	
Sub-total					3200				6400	
Analysis and Reporting Costs	Trident/Micowell CoC analysis	120	18	1	2160	120	18	1	2160	15 samples + 20% QC
	UltraSeep/Lee Meter CoC analysis	120	18	1	2160	120	18	1	2160	15 samples + 20% QC
	On-site data analysis	1000	1	1	1000	1000	1	1	1000	Down select PW and Seepage stations
	Post-survey data analysis	1000	1	3	3000	1000	1	3	3000	1 PI @ 3 days
	Reporting	1000	1	10	10000	1000	1	10	10000	1 PI @ 10 days
Sub-total					18320				18320	
Project Management		1000	1	7.4	7400	1000	1	9.6	9600	@ 10% of labor days
Total Labor Costs					79320				131520	

Table 5-2. Cost analysis for Trident probe and UltraSeep technologies compared to baseline technologies. (continued)

Cost Category	Sub Category	Trident/UltraSeep				Baseline Technology				Details
		Rate	Units	Days	Cost	Rate	Units	Days	Cost	
Non-Labor Costs										
Equipment Costs	Trident	150	1	7	1050					Current per day charge by GSI
	Micro wells					50	60	7	21000	Estimated from AMS
	Water quality analyzer	50	1	7	350	50	1	7	350	Current per day charge by GSI
	UltraSeep	450	3	4	5400					Current per day charge by GSI
	Level logging Piezometers					50	5	4	1000	Estimated from Solinst
	Pressure transducers					50	10	4	2000	Estimated from Solinst
	Lee meters					50	5	4	1000	Current per day charge by GSI
	Sampling pump	50	1	7	350	50	1	12	600	
	Boat rental	500	1	12	6000	500	1	12	6000	Current per day charge by GSI
	Field Computer	25	1	12	300	25	1	12	300	Current per day charge by GSI
Sub-total	Dive Gear	65	3	4	780	65	3	12	2340	Current per day charge by GSI
					14230				34590	
Materials Costs	Calibration standards	10000	1	1	10000	12000	1	1	12000	BT: Larger due to piezometer materials
	Lines and markers									
	Sand packs									
	Cleaning solutions									
	Sampling bags/containers									
	Log books/sheets									
	Fuel									
	Piezometer standpipes									
	Other Misc Supplies									
	Sub-total				10000				12000	
Indirect Activity Costs	IDW Disposal	100	1	1	100	600	1	1	600	T/U: Minimal due to small purge volumes
										BT: Larger due to purge volumes
Sub-total					100				600	
Travel Costs	Airfare	300	3	1	900	300	6	1	1800	
	Per diem	150	3	14	6300	150	5	14	10500	
	Truck/Van	150	1	14	2100	150	1	14	2100	
	Sub-total				9300				14400	
Total non-labor cost					33630				61590	
Project Sub-total					112950				193110	
Fee/Markup @ 8%					9036				15449	
Project Total					121986				208559	

Table 5-3. Rental rates for Trident probe and UltraSeep based on life-cycle costs.

Estimate of Initial Cost for Capital and Ancillary Equipment			
Item	Initial Cost		
Trident Probe	\$ 15,000		
Ancillary - Sampling Pump	\$ 1,500		
Ancillary - Field Computer	\$ 1,000		
Ancillary - Water Quality Analyzer	\$ 1,200		
	Total Trident	\$ 18,700	
UltraSeep	\$ 65,000		
Ancillary - Field Computer	\$ 1,000		
	Total UltraSeep	\$ 66,000	
Equipment Replacement Cost Estimate			
Inflation Rate	4%		
	Years of Use		
	0	5	10
Trident & Ancillary Replacement	\$ 18,700	\$ 22,440	\$ 26,180
UltraSeep & Ancillary Replacement	\$ 66,000	\$ 79,200	\$ 92,400
Estimated Rental Rate Including Inflation and Maintenance			
Maintenance Rate	5%		
	Years of use		
	Uses/year	5	10
Trident & Ancillary	10	\$ 471	\$ 275
	20	\$ 236	\$ 137
	30	\$ 157	\$ 92
	40	\$ 118	\$ 69
	50	\$ 94	\$ 55
	Years of use		
	Uses/year	5	10
UltraSeep & Ancillary	10	\$ 1,663	\$ 970
	20	\$ 832	\$ 485
	30	\$ 554	\$ 323
	40	\$ 416	\$ 243
	50	\$ 333	\$ 194
Current Rental Rates			
Trident Probe	\$ 150		
Ancillary - Sampling Pump	\$ 50		
Ancillary - Field Computer	\$ 25		
Ancillary - Water Quality Analyzer	\$ 50		
	Total Trident	\$ 275	
UltraSeep	\$ 450		
Ancillary - Field Computer	\$ 25		
	Total UltraSeep	\$ 475	

6. IMPLEMENTATION ISSUES

6.1 ENVIRONMENTAL CHECKLIST

No special environmental permits or regulatory notice requirements were required for the demonstration. All participants were required to comply with security and safety regulations and requirements while working at the demonstration site. All of the site team personnel were notified and pre-briefed on the demonstration. Safety and environmental personnel at the bases were also notified. For equipment that was deployed in offshore areas that could create a hazard to navigation, and for diving operations in navigable waters, notice to relevant local agencies was provided.

6.2 OTHER REGULATORY ISSUES

The demonstration results were incorporated into the evaluation of corrective actions for the NSA Panama City AOC1 assessment, and at NTC Orlando for the OU 4 assessment. These results were available for review and comment to relevant local, state, and federal regulators, and stakeholders. The Cal/EPA Department of Toxic Substances Control is currently conducting a regulatory review. The California EPA will provide formal review and comment on the Trident probe and UltraSeep demonstrations through the Cal/EPA Hazardous Waste Technology Demonstration Program.

6.3 END-USER ISSUES

For the NSA Panama City demonstration, end-user and stakeholder buy-in for this technology was significant, as evidenced by the incorporation of the technology into the regulatory program for the assessment of potential corrective measures at AOC 1. End-user concerns, reservations, and decision-making factors were assessed throughout the demonstrations, and to the extent possible, these issues were addressed either through modifications to the technology, or to the methodologies that describe its use.

The demonstration were based on the commercial off-the-shelf (COTS) Trident probe and UltraSeep systems that were produced in collaboration with the Oceanscience Group. Modifications that were incorporated after the NSA Panama City demonstration included installation of a sand pack filter on the Trident probe porewater sampler, and installation of a gas bubble deflector and gas trap on the UltraSeep.

For the NTC Orlando demonstration, end-user and stakeholder buy-in for this technology was also significant, as evidenced by the incorporation of the technology into the regulatory program for the assessment of potential corrective measures at OU 4. End-user concerns, reservations, and decision-making factors were assessed throughout the demonstrations, and to the extent possible, these issues were addressed through modifications to the technology, or the methodologies that describe its use.

The demonstration was based on the COTS Trident probe and UltraSeep systems that were produced in collaboration with the Oceanscience Group. No significant modifications or customization was adopted following the demonstration.

Technology transfer of the migration monitoring technologies to the numerous DoD activities that could use this technology has been accomplished through the publication of articles, distribution of pamphlets, the presentation of test results at conferences, and Web page and Web tool publication on Navy and EPA public access sites. Articles were submitted

to the Navy's environmental magazine, *Currents*, and the NSA Panama City results were cited in the Navy's 5-Year IR Report as a success story.

As stated previously, commercial equipment suppliers and service providers have already been identified and are currently applying the technologies at a number of sites. Together, these efforts should help transition this technology to more DoD activities.

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Principal Investigator Approval

Signature

Date

APPENDIX A
ANALYTICAL METHODS SUPPORTING
THE EXPERIMENTAL DESIGN

A.1 TRIDENT PROBE CALIBRATION RESULTS

Table A-1. Results for Trident probe and reference sensor temperature calibration (NSA Panama City).

SeaBird Standard	Trident Probe Sensor				
(C)	Raw (C)	Cal (C)	Residual (C)	Abs Res (C)	Stdev Res (C)
5.033	2.682	5.053	-0.020	0.020	0.014
5.033	2.675	5.047	-0.013	0.013	
5.033	2.666	5.038	-0.005	0.005	
5.033	2.657	5.030	0.003	0.003	
5.034	2.649	5.022	0.012	0.012	
5.033	2.656	5.029	0.004	0.004	
5.031	2.635	5.009	0.021	0.021	
34.947	34.792	34.852	0.096	0.096	0.043
34.791	34.731	34.795	-0.004	0.004	
34.719	34.657	34.726	-0.007	0.007	
34.663	34.607	34.680	-0.017	0.017	
34.559	34.501	34.582	-0.022	0.022	
34.510	34.446	34.531	-0.021	0.021	
34.452	34.388	34.477	-0.025	0.025	

Calibration Coefficients		Min:	0.003	0.014
Slope	0.928	Max:	0.096	0.043
Offset	2.564	Avg:	0.019	0.029

SeaBird Standard	Trident Reference Sensor				
(C)	Raw (C)	Cal (C)	Residual (C)	Abs Res (C)	Stdev Res (C)
5.033	1.415	4.993	0.040	0.040	0.028
5.033	1.428	5.005	0.028	0.028	
5.033	1.449	5.024	0.009	0.009	
5.033	1.461	5.034	-0.002	0.002	
5.034	1.472	5.044	-0.010	0.010	
5.033	1.488	5.059	-0.026	0.026	
5.031	1.501	5.069	-0.039	0.039	
34.947	34.883	34.845	0.102	0.102	0.047
34.791	34.817	34.786	0.005	0.005	
34.719	34.747	34.723	-0.004	0.004	
34.663	34.696	34.678	-0.015	0.015	
34.559	34.591	34.584	-0.025	0.025	
34.510	34.541	34.539	-0.030	0.030	
34.452	34.481	34.486	-0.035	0.035	

Calibration Coefficients		Min:	0.002	0.028
Slope	0.892	Max:	0.102	0.047
Offset	3.731	Avg:	0.026	0.038

Table A-2. Results for Trident probe and reference sensor conductivity calibration (NSA Panama City).

NIST Standard			Trident Probe Sensor				
Raw NIST (mS/cm)	NIST Temp (C)	Temp Corr NIST (mS/cm)	Raw Ref (mS/cm)	Cal Ref (mS/cm)	Residual (mS/cm)	RPD (% FS)	StDev Res (mS/cm)
5.69	24.8	5.71276	6.080	5.316	0.397	0.8%	0.001
5.69	24.8	5.71276	6.080	5.316	0.397	0.8%	
5.69	24.8	5.71276	6.080	5.316	0.397	0.8%	
5.69	24.8	5.71276	6.082	5.318	0.395	0.8%	
17.6	24.7	17.7056	16.922	17.767	-0.061	0.1%	0.036
17.6	24.7	17.7056	16.948	17.801	-0.096	0.2%	
17.6	24.7	17.7056	16.967	17.827	-0.121	0.2%	
17.6	24.7	17.7056	16.985	17.851	-0.145	0.3%	
48.6	24.6	48.9888	35.630	48.208	0.781	1.6%	0.271
48.6	24.6	48.9888	35.772	48.482	0.507	1.0%	
48.6	24.6	48.9888	35.865	48.662	0.327	0.7%	
48.6	24.6	48.9888	35.958	48.842	0.146	0.3%	

Calibration Coefficients	
Slope	1.47835618
Intercept	-4.8608814
A2	0.0162
A1	0.7758

Min	0.1%	0.001
Max	1.6%	0.271
Avg	0.6%	0.102

Full Scale	48.9888
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NIST Standard			Trident Reference Sensor				
Raw NIST (mS/cm)	NIST Temp (C)	Temp Corr NIST (mS/cm)	Raw Ref (mS/cm)	Cal Ref (mS/cm)	Residual (mS/cm)	RPD (% FS)	StDev Res (mS/cm)
5.69	24.8	5.71276	5.600	5.701	0.012	0.0%	0.000
5.69	24.8	5.71276	5.600	5.701	0.012	0.0%	
5.69	24.8	5.71276	5.600	5.701	0.012	0.0%	
5.69	24.8	5.71276	5.600	5.701	0.012	0.0%	
17.6	24.7	17.7056	16.133	17.544	0.161	0.3%	0.040
17.6	24.7	17.7056	16.200	17.624	0.081	0.2%	
17.6	24.7	17.7056	16.200	17.624	0.081	0.2%	
17.6	24.7	17.7056	16.200	17.624	0.081	0.2%	
48.6	24.6	48.9888	39.150	48.522	0.467	1.0%	0.154
48.6	24.6	48.9888	39.200	48.597	0.392	0.8%	
48.6	24.6	48.9888	39.200	48.597	0.392	0.8%	
48.6	24.6	48.9888	39.383	48.871	0.117	0.2%	

Calibration Coefficients	
Slope	1.29809902
Intercept	-2.2660996
A2	0.0066
A1	0.981

Min	0.0%	0.000
Max	1.0%	0.154
Avg	0.3%	0.065

Full Scale	48.9888
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Table A-3. Results for Trident probe and reference sensor temperature calibration (NTC Orlando).

SeaBird Standard	Trident Probe Sensor				
(C)	Raw (C)	Cal (C)	Residual (C)	Abs Res (C)	Stdev Res (C)
15.783	15.553	15.835	-0.052	0.052	0.030
15.780	15.471	15.754	0.026	0.026	
15.778	15.487	15.770	0.009	0.009	
15.786	15.492	15.775	0.011	0.011	
15.781	15.492	15.775	0.006	0.006	
32.402	32.383	32.400	0.002	0.002	0.003
32.391	32.373	32.390	0.001	0.001	
32.386	32.367	32.384	0.002	0.002	
32.378	32.362	32.379	-0.001	0.001	
32.366	32.354	32.371	-0.005	0.005	

Calibration Coefficients	Min:	0.001	0.003
Slope	Max:	0.052	0.030
Offset	Avg:	0.011	0.017

SeaBird Standard	Trident Reference Sensor				
(C)	Raw (C)	Cal (C)	Residual (C)	Abs Res (C)	Stdev Res (C)
15.783	15.848	15.793	-0.010	0.010	0.008
15.780	15.829	15.774	0.006	0.006	
15.778	15.840	15.785	-0.006	0.006	
15.786	15.833	15.778	0.009	0.009	
15.781	15.835	15.780	0.001	0.001	
32.402	32.521	32.401	0.001	0.001	0.002
32.391	32.508	32.389	0.003	0.003	
32.386	32.504	32.385	0.001	0.001	
32.378	32.501	32.382	-0.003	0.003	
32.366	32.487	32.368	-0.001	0.001	

Calibration Coefficients	Min:	0.001	0.002
Slope	Max:	0.010	0.008
Offset	Avg:	0.004	0.005

Table A-4. Results for Trident probe and reference sensor conductivity calibration results (NTC Orlando).

NIST Standard			Trident Probe Sensor				
Raw NIST (mS/cm)	NIST Temp (C)	Temp Corr NIST (mS/cm)	Raw Ref (mS/cm)	Cal Ref (mS/cm)	Residual (mS/cm)	RPD (% FS)	StDev Res (mS/cm)
3.9	23.565	4.01	4.280	3.453	0.559	0.6%	0.001
3.9	23.549	4.01	4.280	3.453	0.560	0.6%	
3.9	23.533	4.01	4.280	3.453	0.562	0.6%	
7	23.537	7.20	7.790	6.980	0.225	0.2%	0.001
7	23.544	7.20	7.790	6.980	0.224	0.2%	
14	23.495	14.42	15.995	15.225	-0.803	0.8%	0.003
14	23.514	14.42	15.995	15.225	-0.809	0.8%	
14	23.511	14.42	15.993	15.223	-0.806	0.8%	
94.9	23.44	97.86	98.285	97.915	-0.054	0.1%	0.420
94.9	23.409	97.92	98.517	98.148	-0.228	0.2%	
94.9	23.385	97.97	97.768	97.395	0.570	0.6%	

Calibration Coefficients	
Slope	1.00485926
Intercept	-0.8479267
A2	
A1	

Min	0.1%	0.001
Max	0.8%	0.420
Avg	0.5%	0.106

Full Scale	97.92
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NIST Standard			Trident Reference Sensor				
Raw NIST (mS/cm)	NIST Temp (C)	Temp Corr NIST (mS/cm)	Raw Ref (mS/cm)	Cal Ref (mS/cm)	Residual (mS/cm)	RPD (% FS)	StDev Res (mS/cm)
3.9	23.565	4.01	4.300	4.825	-0.813	1.1%	0.001
3.9	23.549	4.01	4.300	4.825	-0.812	1.1%	
3.9	23.533	4.01	4.300	4.825	-0.811	1.1%	
7	23.537	7.20	7.600	7.394	-0.189	0.2%	0.001
7	23.544	7.20	7.600	7.394	-0.190	0.2%	
14	23.495	14.42	15.300	13.388	1.033	1.3%	0.003
14	23.514	14.42	15.300	13.388	1.028	1.3%	
14	23.511	14.42	15.300	13.388	1.029	1.3%	
94.9	23.44	97.86	123.950	97.965	-0.105	0.1%	0.028
94.9	23.409	97.92	124.033	98.030	-0.110	0.1%	
94.9	23.385	97.97	124.025	98.024	-0.059	0.1%	

Calibration Coefficients	
Slope	0.77843775
Intercept	1.47809054
A2	0.0066
A1	0.981

Min	0.1%	0.001
Max	1.3%	0.028
Avg	0.7%	0.008

Full Scale	77.040697
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A-2 ULTRASEEP CALIBRATION RESULTS

Table A-5. Results for UltraSeep temperature calibration (NSA Panama City).

SeaBird Standard (C)	UltraSeep Sensor				
	Raw (C)	Cal (C)	Residual (C)	Abs Res (C)	Stdev Res (C)
4.470	2.275	4.400	0.070	0.070	0.024
4.449	2.275	4.400	0.049	0.049	
4.428	2.270	4.395	0.033	0.033	
4.428	2.275	4.400	0.028	0.028	
4.418	2.275	4.400	0.018	0.018	
4.409	2.273	4.398	0.011	0.011	
4.408	2.279	4.404	0.004	0.004	
4.405	2.279	4.404	0.001	0.001	
4.401	2.279	4.404	-0.003	0.003	
4.402	2.278	4.403	0.000	0.000	
32.180	31.990	32.214	-0.034	0.034	0.032
32.179	31.978	32.202	-0.023	0.023	
32.176	31.965	32.190	-0.014	0.014	
32.183	31.950	32.176	0.007	0.007	
32.178	31.937	32.164	0.014	0.014	
32.177	31.923	32.151	0.026	0.026	
32.175	31.913	32.141	0.034	0.034	
32.175	31.904	32.133	0.042	0.042	
32.177	31.896	32.126	0.052	0.052	
32.179	31.888	32.118	0.061	0.061	
16.487	15.256	16.550	-0.063	0.063	0.014
16.489	15.247	16.542	-0.053	0.053	
16.488	15.241	16.536	-0.048	0.048	
16.487	15.232	16.528	-0.041	0.041	
16.485	15.226	16.522	-0.037	0.037	
16.484	15.220	16.517	-0.032	0.032	
16.486	15.217	16.514	-0.028	0.028	
16.485	15.215	16.512	-0.027	0.027	
16.484	15.212	16.509	-0.025	0.025	
16.486	15.210	16.507	-0.021	0.021	

Calibration Coefficients	
Slope	0.936
Offset	2.271

Min:	0.00	0.01
Max:	0.07	0.03
Avg:	0.03	0.02

Table A-6. Results for UltraSeep conductivity calibration (NSA Panama City).

NIST Standard			UltraSeep Sensor				
Raw NIST (mS/cm)	NIST Temp (C)	Temp Corr NIST (mS/cm)	Raw Ultra (mS/cm)	Cal Ultra (mS/cm)	Residual (mS/cm)	RPD (% FS)	StDev Res (mS/cm)
5.69	24.8	5.71276	6.840	5.792	-0.079	0.2%	0.007
5.69	24.8	5.71276	6.850	5.800	-0.087	0.2%	
5.69	24.8	5.71276	6.850	5.800	-0.087	0.2%	
5.69	24.8	5.71276	6.860	5.808	-0.096	0.2%	
17.6	24.7	17.7056	20.950	17.586	0.120	0.2%	0.018
17.6	24.7	17.7056	20.970	17.602	0.103	0.2%	
17.6	24.7	17.7056	20.960	17.594	0.112	0.2%	
17.6	24.7	17.7056	20.920	17.560	0.145	0.3%	
48.6	24.6	48.9888	58.530	48.996	-0.008	0.0%	0.038
48.6	24.6	48.9888	58.570	49.030	-0.041	0.1%	
48.6	24.6	48.9888	58.620	49.072	-0.083	0.2%	
48.6	24.6	48.9888	58.520	48.988	0.001	0.0%	

Calibration Coefficients	
Slope	0.83584174
Intercept	0.07462237
A2	0.0066
A1	0.981

Min	0.0%	0.01
Max	0.3%	0.04
Avg	0.2%	0.02

Full Scale	48.9888
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Table A-7. Results for UltraSeep flow meter calibration results (NSA Panama City).

Seep Meter:	US1
Date:	7/1/2004
Kc for Cal	0.00
By:	Bart/Jon

0 = Intrinsic

Condition	Time (min)	Totalizer (ml)			Grad Cylinder (ml)			Avg Totalizer		Avg Grad Cylinder	
		Rep1	Rep2	Rep3	Rep1	Rep2	Rep3	Flow (ml)	Vel (ml/min)	Flow (ml)	Vel (ml/min)
Zero	1.5	0.49758	-1.47827	1.57323	0	0	0	0.20	0.13	0.00	0.00
Low	1.5	2.30769	3.28153	4.30991	3.84	3.9	3.9	3.30	2.20	3.88	2.59
Mid	1.5	19.77727	20.9139	21.05355	18.5	18.8	18.5	20.58	13.72	18.60	12.40
High	1.5	66.82782	66.71013	65.29627	66.3	66.5	66	66.28	44.19	66.27	44.18

Slope =	1.00
Intercept=	-0.23
R ² =	1.00
Kc=	-0.2%

All Data						
Raw Totalizer (ml/min)	Grad Cylinder (ml/min)	Cal Totalizer (ml/min)	Residual (ml/min)	Residual (cm/d)	Abs Residual (cm/d)	Stdev Residual (cm/d)
0.33	0.00	0.10	-0.10	-0.07	0.07	
-0.99	0.00	-1.22	1.22	0.89	0.89	
1.05	0.00	0.81	-0.81	-0.60	0.60	0.42
1.54	2.56	1.30	1.26	0.92	0.92	
2.19	2.60	1.95	0.65	0.48	0.48	
2.87	2.60	2.63	-0.03	-0.02	0.02	0.45
13.18	12.33	12.92	-0.59	-0.43	0.43	
13.94	12.53	13.68	-1.14	-0.84	0.84	
14.04	12.33	13.77	-1.44	-1.05	1.05	0.32
44.55	44.20	44.22	-0.02	-0.01	0.01	
44.47	44.33	44.14	0.19	0.14	0.14	
43.53	44.00	43.20	0.80	0.59	0.59	0.30

Mean	0.50	0.37
Min	0.01	0.30
Max	1.05	0.45

Table A-8. Results for UltraSeep temperature calibration (NTC Orlando).

SeaBird Standard		UltraSeep Sensor			
(C)	Raw (C)	Cal (C)	Residual (C)	Abs Res (C)	Stdev Res (C)
17.866	18.367	17.884	-0.018	0.018	0.045
17.875	18.401	17.918	-0.044	0.044	
17.884	18.376	17.893	-0.009	0.009	
17.893	18.382	17.899	-0.006	0.006	
17.905	18.312	17.828	0.077	0.077	
31.754	32.000	31.730	0.023	0.023	0.022
31.699	31.972	31.702	-0.003	0.003	
31.643	31.934	31.663	-0.020	0.020	

Calibration Coefficients		Min:	
Slope	1.016	0.00	0.02
Offset	-0.771	0.08	0.05
		Avg:	0.03

Table A-9. UltraSeep conductivity calibration results for Panama City.

NIST Standard			UltraSeep Sensor				
Raw NIST (mS/cm)	NIST Temp (C)	Temp Corr NIST (mS/cm)	Raw Ref (mS/cm)	Cal Ref (mS/cm)	Residual (mS/cm)	RPD (% FS)	StDev Res (mS/cm)
3.9	24.386	3.95	0.000	3.561	0.387	0.5%	0.010
3.9	24.268	3.96	0.000	3.561	0.396	0.5%	
3.9	24.168	3.96	0.000	3.561	0.404	0.5%	
3.9	24.096	3.97	0.000	3.561	0.410	0.5%	
3.9	24.057	3.97	0.000	3.561	0.413	0.5%	
7	23.678	7.19	8.920	8.475	-1.290	1.7%	0.001
7	23.687	7.18	8.920	8.475	-1.291	1.7%	
7	23.686	7.18	8.920	8.475	-1.291	1.7%	
14	23.572	14.40	18.550	13.780	0.620	0.8%	0.001
14	23.569	14.40	18.550	13.780	0.621	0.8%	
14	23.565	14.40	18.550	13.780	0.622	0.8%	

Calibration Coefficients		Min:	
Slope	0.55090991	0.5%	0.001
Intercept	3.56078586	Max	0.010
A2	0.0066	Avg	0.9%
A1	0.981		0.004

Full Scale	14.4018
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Table A-10. Results for UltraSeep flow meter calibration (NTC Orlando).

Seep Meter:	US1
Date:	7/1/2004
Kc for Cal	0.00
By:	Bart/Jon

0 = Intrinsic

Condition	Time (min)	Totalizer (ml)			Grad Cylinder (ml)			Avg Totalizer Flow (ml)	Avg Vel Flow (ml/min)	Avg Vel (ml/min)
		Rep1	Rep2	Rep3	Rep1	Rep2	Rep3			
Zero	1	0.44	-0.85	0.28	0	0	0	-0.04	-0.04	0.00
Low	1	3.3	3.1	3.2	3.1	3.1	3.1	3.20	3.20	3.10
Mid	1	6.7	7.3	8	7.3	7.9	7.7	7.33	7.33	7.63
High	1	14.5	14.5	14.3	14	14	14	14.43	14.43	14.00

Slope =	0.97
Intercept=	0.15
R ² =	0.99
Kc=	-3.2%

All Data						
Raw Totalizer (ml/min)	Grad Cylinder (ml/min)	Cal Totalizer (ml/min)	Residual (ml/min)	Residual (cm/d)	Abs Residual (cm/d)	Stdev Residual (cm/d)
0.44	0.00	0.58	-0.58	-0.42	0.42	
-0.85	0.00	-0.67	0.67	0.49	0.49	
0.28	0.00	0.42	-0.42	-0.31	0.31	0.09
3.30	3.10	3.35	-0.25	-0.18	0.18	
3.10	3.10	3.15	-0.05	-0.04	0.04	
3.20	3.10	3.25	-0.15	-0.11	0.11	0.07
6.70	7.30	6.64	0.66	0.49	0.49	
7.30	7.90	7.22	0.68	0.50	0.50	
8.00	7.70	7.90	-0.20	-0.14	0.14	0.20
14.50	14.00	14.19	-0.19	-0.14	0.14	
14.50	14.00	14.19	-0.19	-0.14	0.14	
14.30	14.00	14.00	0.00	0.00	0.00	0.08

Mean	0.25	0.11
Min	0.00	0.07
Max	0.50	0.20

APPENDIX B

ANALYTICAL METHODS

SUPPORTING THE SAMPLING PLAN

B.1. U.S. EPA METHOD 8260B SUMMARY

METHOD 8260B
VOLATILE ORGANIC COMPOUNDS BY GAS CHROMATOGRAPHY/
MASS SPECTROMETRY (GC/MS)

1.0 SCOPE AND APPLICATION

1.1 Method 8260 is used to determine volatile organic compounds in a variety of solid waste matrices. This method is applicable to nearly all types of samples, regardless of water content, including various air sampling trapping media, ground and surface water, aqueous sludges, caustic liquors, acid liquors, waste solvents, oily wastes, mousses, tars, fibrous wastes, polymeric emulsions, filter cakes, spent carbons, spent catalysts, soils, and sediments. The following compounds can be determined by this method:

Compound	CAS No. ^b	Appropriate Preparation Technique ^a					
		5030/ 5035	5031	5032	5021	5041	Direct Inject.
Acetone	67-64-1	pp	c	c	nd	c	c
Acetonitrile	75-05-8	pp	c	nd	nd	nd	c
Acrolein (Propenal)	107-02-8	pp	c	c	nd	nd	c
Acrylonitrile	107-13-1	pp	c	c	nd	c	c
Allyl alcohol	107-18-6	ht	c	nd	nd	nd	c
Allyl chloride	107-05-1	c	nd	nd	nd	nd	c
Benzene	71-43-2	c	nd	c	c	c	c
Benzyl chloride	100-44-7	c	nd	nd	nd	nd	c
Bis(2-chloroethyl)sulfide	505-60-2	pp	nd	nd	nd	nd	c
Bromoacetone	598-31-2	pp	nd	nd	nd	nd	c
Bromochloromethane	74-97-5	c	nd	c	c	c	c
Bromodichloromethane	75-27-4	c	nd	c	c	c	c
4-Bromofluorobenzene (surr)	460-00-4	c	nd	c	c	c	c
Bromoform	75-25-2	c	nd	c	c	c	c
Bromomethane	74-83-9	c	nd	c	c	c	c
n-Butanol	71-36-3	ht	c	nd	nd	nd	c
2-Butanone (MEK)	78-93-3	pp	c	c	nd	nd	c
t-Butyl alcohol	75-65-0	pp	c	nd	nd	nd	c
Carbon disulfide	75-15-0	pp	nd	c	nd	c	c
Carbon tetrachloride	56-23-5	c	nd	c	c	c	c
Chloral hydrate	302-17-0	pp	nd	nd	nd	nd	c
Chlorobenzene	108-90-7	c	nd	c	c	c	c
Chlorobenzene-d ₆ (IS)		c	nd	c	c	c	c
Chlorodibromomethane	124-48-1	c	nd	c	nd	c	c
Chloroethane	75-00-3	c	nd	c	c	c	c
2-Chloroethanol	107-07-3	pp	nd	nd	nd	nd	c
2-Chloroethyl vinyl ether	110-75-8	c	nd	c	nd	nd	c
Chloroform	67-66-3	c	nd	c	c	c	c
Chloromethane	74-87-3	c	nd	c	c	c	c
Chloroprene	126-99-8	c	nd	nd	nd	nd	c
3-Chloropropionitrile	542-76-7	l	nd	nd	nd	nd	pc

(continued)

Compound	CAS No. ^b	Appropriate Preparation Technique ^a					
		5030/ 5035	5031	5032	5021	5041	Direct Inject.
Crotonaldehyde	4170-30-3	pp	c	nd	nd	nd	c
1,2-Dibromo-3-chloropropane	96-12-8	pp	nd	nd	c	nd	c
1,2-Dibromoethane	106-93-4	c	nd	nd	c	nd	c
Dibromomethane	74-95-3	c	nd	c	c	c	c
1,2-Dichlorobenzene	95-50-1	c	nd	nd	c	nd	c
1,3-Dichlorobenzene	541-73-1	c	nd	nd	c	nd	c
1,4-Dichlorobenzene	106-46-7	c	nd	nd	c	nd	c
1,4-Dichlorobenzene-d ₄ (IS)		c	nd	nd	c	nd	c
cis-1,4-Dichloro-2-butene	1476-11-5	c	nd	c	nd	nd	c
trans-1,4-Dichloro-2-butene	110-57-6	pp	nd	c	nd	nd	c
Dichlorodifluoromethane	75-71-8	c	nd	c	c	nd	c
1,1-Dichloroethane	75-34-3	c	nd	c	c	c	c
1,2-Dichloroethane	107-06-2	c	nd	c	c	c	c
1,2-Dichloroethane-d ₄ (surr)		c	nd	c	c	c	c
1,1-Dichloroethene	75-35-4	c	nd	c	c	c	c
trans-1,2-Dichloroethene	156-60-5	c	nd	c	c	c	c
1,2-Dichloropropane	78-87-5	c	nd	c	c	c	c
1,3-Dichloro-2-propanol	96-23-1	pp	nd	nd	nd	nd	c
cis-1,3-Dichloropropene	10061-01-5	c	nd	c	nd	c	c
trans-1,3-Dichloropropene	10061-02-6	c	nd	c	nd	c	c
1,2,3,4-Diepoxybutane	1464-53-5	c	nd	nd	nd	nd	c
Diethyl ether	60-29-7	c	nd	nd	nd	nd	c
1,4-Difluorobenzene (IS)	540-36-3	nd	nd	nd	nd	c	nd
1,4-Dioxane	123-91-1	pp	c	c	nd	nd	c
Epichlorohydrin	106-89-8	l	nd	nd	nd	nd	c
Ethanol	64-17-5	l	c	c	nd	nd	c
Ethyl acetate	141-78-6	l	c	nd	nd	nd	c
Ethylbenzene	100-41-4	c	nd	c	c	c	c
Ethylene oxide	75-21-8	pp	c	nd	nd	nd	c
Ethyl methacrylate	97-63-2	c	nd	c	nd	nd	c
Fluorobenzene (IS)	462-06-6	c	nd	nd	nd	nd	nd
Hexachlorobutadiene	87-68-3	c	nd	nd	c	nd	c
Hexachloroethane	67-72-1	l	nd	nd	nd	nd	c
2-Hexanone	591-78-6	pp	nd	c	nd	nd	c
2-Hydroxypropionitrile	78-97-7	l	nd	nd	nd	nd	pc
Iodomethane	74-88-4	c	nd	c	nd	c	c
Isobutyl alcohol	78-83-1	pp	c	nd	nd	nd	c
Isopropylbenzene	98-82-8	c	nd	nd	c	nd	c
Malononitrile	109-77-3	pp	nd	nd	nd	nd	c
Methacrylonitrile	126-98-7	pp	l	nd	nd	nd	c
Methanol	67-56-1	l	c	nd	nd	nd	c
Methylene chloride	75-09-2	c	nd	c	c	c	c
Methyl methacrylate	80-62-6	c	nd	nd	nd	nd	c
4-Methyl-2-pentanone (MIBK)	108-10-1	pp	c	c	nd	nd	c
Naphthalene	91-20-3	c	nd	nd	c	nd	c

(continued)

Compound	CAS No. ^b	Appropriate Preparation Technique ^a					
		5030/ 5035	5031	5032	5021	5041	Direct Inject.
Nitrobenzene	98-95-3	c	nd	nd	nd	nd	c
2-Nitropropane	79-46-9	c	nd	nd	nd	nd	c
N-Nitroso-di-n-butylamine	924-16-3	pp	c	nd	nd	nd	c
Paraldehyde	123-63-7	pp	c	nd	nd	nd	c
Pentachloroethane	76-01-7	l	nd	nd	nd	nd	c
2-Pantanone	107-87-9	pp	c	nd	nd	nd	c
2-Picoline	109-06-8	pp	c	nd	nd	nd	c
1-Propanol	71-23-8	pp	c	nd	nd	nd	c
2-Propanol	67-63-0	pp	c	nd	nd	nd	c
Propargyl alcohol	107-19-7	pp	l	nd	nd	nd	c
β-Propiolactone	57-57-8	pp	nd	nd	nd	nd	c
Propionitrile (ethyl cyanide)	107-12-0	ht	c	nd	nd	nd	pc
n-Propylamine	107-10-8	c	nd	nd	nd	nd	c
Pyridine	110-86-1	l	c	nd	nd	nd	c
Styrene	100-42-5	c	nd	c	c	c	c
1,1,1,2-Tetrachloroethane	630-20-6	c	nd	c	c	c	c
1,1,2,2-Tetrachloroethane	79-34-5	c	nd	c	c	c	c
Tetrachloroethene	127-18-4	c	nd	c	c	c	c
Toluene	108-88-3	c	nd	c	c	c	c
Toluene-d ₈ (surr)	2037-26-5	c	nd	c	c	c	c
o-Toluidine	95-53-4	pp	c	nd	nd	nd	c
1,2,4-Trichlorobenzene	120-82-1	c	nd	nd	c	nd	c
1,1,1-Trichloroethane	71-55-6	c	nd	c	c	c	c
1,1,2-Trichloroethane	79-00-5	c	nd	c	c	c	c
Trichloroethene	79-01-6	c	nd	c	c	c	c
Trichlorofluoromethane	75-69-4	c	nd	c	c	c	c
1,2,3-Trichloropropane	96-18-4	c	nd	c	c	c	c
Vinyl acetate	108-05-4	c	nd	c	nd	nd	c
Vinyl chloride	75-01-4	c	nd	c	c	c	c
o-Xylene	95-47-6	c	nd	c	c	c	c
m-Xylene	108-38-3	c	nd	c	c	c	c
p-Xylene	106-42-3	c	nd	c	c	c	c

^a See Sec. 1.2 for other appropriate sample preparation techniques

^b Chemical Abstract Service Registry Number

- c = Adequate response by this technique
- ht = Method analyte only when purged at 80°C
- nd = Not determined
- l = Inappropriate technique for this analyte
- pc = Poor chromatographic behavior
- pp = Poor purging efficiency resulting in high Estimated Quantitation Limits
- surr = Surrogate
- IS = Internal Standard

1.2 There are various techniques by which these compounds may be introduced into the GC/MS system. The more common techniques are listed in the table above. Purge-and-trap, by Methods 5030 (aqueous samples) and 5035 (solid and waste oil samples), is the most commonly used technique for volatile organic analytes. However, other techniques are also appropriate and necessary for some analytes. These include direct injection following dilution with hexadecane (Method 3585) for waste oil samples; automated static headspace by Method 5021 for solid samples; direct injection of an aqueous sample (concentration permitting) or injection of a sample concentrated by azeotropic distillation (Method 5031); and closed system vacuum distillation (Method 5032) for aqueous, solid, oil and tissue samples. For air samples, Method 5041 provides methodology for desorbing volatile organics from trapping media (Methods 0010, 0030, and 0031). In addition, direct analysis utilizing a sample loop is used for sub-sampling from Tedlar® bags (Method 0040). Method 5000 provides more general information on the selection of the appropriate introduction method.

1.3 Method 8260 can be used to quantitate most volatile organic compounds that have boiling points below 200°C. Volatile, water soluble compounds can be included in this analytical technique by the use of azeotropic distillation or closed-system vacuum distillation. Such compounds include low molecular weight halogenated hydrocarbons, aromatics, ketones, nitriles, acetates, acrylates, ethers, and sulfides. See Tables 1 and 2 for analytes and retention times that have been evaluated on a purge-and-trap GC/MS system. Also, the method detection limits for 25-mL sample volumes are presented. The following compounds are also amenable to analysis by Method 8260:

Bromobenzene	1,3-Dichloropropane
n-Butylbenzene	2,2-Dichloropropane
sec-Butylbenzene	1,1-Dichloropropene
tert-Butylbenzene	p-Isopropyltoluene
Chloroacetonitrile	Methyl acrylate
1-Chlorobutane	Methyl-t-butyl ether
1-Chlorohexane	Pentafluorobenzene
2-Chlorotoluene	n-Propylbenzene
4-Chlorotoluene	1,2,3-Trichlorobenzene
Dibromofluoromethane	1,2,4-Trimethylbenzene
cis-1,2-Dichloroethene	1,3,5-Trimethylbenzene

1.4 The estimated quantitation limit (EQL) of Method 8260 for an individual compound is somewhat instrument dependent and also dependent on the choice of sample preparation/introduction method. Using standard quadrupole instrumentation and the purge-and-trap technique, limits should be approximately 5 µg/kg (wet weight) for soil/sediment samples, 0.5 mg/kg (wet weight) for wastes, and 5 µg/L for ground water (see Table 3). Somewhat lower limits may be achieved using an ion trap mass spectrometer or other instrumentation of improved design. No matter which instrument is used, EQLs will be proportionately higher for sample extracts and samples that require dilution or when a reduced sample size is used to avoid saturation of the detector.

1.5 This method is restricted to use by, or under the supervision of, analysts experienced in the use of gas chromatograph/mass spectrometers, and skilled in the interpretation of mass spectra and their use as a quantitative tool.

2.0 SUMMARY OF METHOD

2.1 The volatile compounds are introduced into the gas chromatograph by the purge-and-trap method or by other methods (see Sec. 1.2). The analytes are introduced directly to a wide-bore capillary column or cryofocussed on a capillary pre-column before being flash evaporated to a narrow-bore capillary for analysis. The column is temperature-programmed to separate the analytes, which are then detected with a mass spectrometer (MS) interfaced to the gas chromatograph (GC).

2.2 Analytes eluted from the capillary column are introduced into the mass spectrometer via a jet separator or a direct connection. (Wide-bore capillary columns normally require a jet separator, whereas narrow-bore capillary columns may be directly interfaced to the ion source). Identification of target analytes is accomplished by comparing their mass spectra with the electron impact (or electron impact-like) spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using a five-point calibration curve.

2.3 The method includes specific calibration and quality control steps that supersede the general requirements provided in Method 8000.

3.0 INTERFERENCES

3.1 Major contaminant sources are volatile materials in the laboratory and impurities in the inert purging gas and in the sorbent trap. The use of non-polytetrafluoroethylene (PTFE) thread sealants, plastic tubing, or flow controllers with rubber components should be avoided, since such materials out-gas organic compounds which will be concentrated in the trap during the purge operation. Analyses of calibration and reagent blanks provide information about the presence of contaminants. When potential interfering peaks are noted in blanks, the analyst should change the purge gas source and regenerate the molecular sieve purge gas filter. Subtracting blank values from sample results is not permitted. If reporting values without correcting for the blank results in what the laboratory feels is a false positive result for a sample, the laboratory should fully explained this in text accompanying the uncorrected data.

3.2 Contamination may occur when a sample containing low concentrations of volatile organic compounds is analyzed immediately after a sample containing high concentrations of volatile organic compounds. A technique to prevent this problem is to rinse the purging apparatus and sample syringes with two portions of organic-free reagent water between samples. After the analysis of a sample containing high concentrations of volatile organic compounds, one or more blanks should be analyzed to check for cross-contamination. Alternatively, if the sample immediately following the high concentration sample does not contain the volatile organic compounds present in the high level sample, freedom from contamination has been established.

3.3 For samples containing large amounts of water-soluble materials, suspended solids, high boiling compounds, or high concentrations of compounds being determined, it may be necessary to wash the purging device with a soap solution, rinse it with organic-free reagent water, and then dry the purging device in an oven at 105°C. In extreme situations, the entire purge-and-trap device may require dismantling and cleaning. Screening of the samples prior to purge-and-trap GC/MS analysis is highly recommended to prevent contamination of the system. This is especially true for soil and waste samples. Screening may be accomplished with an automated headspace technique (Method 5021) or by Method 3820 (Hexadecane Extraction and Screening of Purgeable Organics).

3.4 Many analytes exhibit low purging efficiencies from a 25-mL sample. This often results in significant amounts of these analytes remaining in the sample purge vessel after analysis. After removal of the sample aliquot that was purged, and rinsing the purge vessel three times with organic-free water, the empty vessel should be subjected to a heated purge cycle prior to the analysis of another sample in the same purge vessel. This will reduce sample-to-sample carryover.

3.5 Special precautions must be taken to analyze for methylene chloride. The analytical and sample storage area should be isolated from all atmospheric sources of methylene chloride. Otherwise, random background levels will result. Since methylene chloride will permeate through PTFE tubing, all gas chromatography carrier gas lines and purge gas plumbing should be constructed from stainless steel or copper tubing. Laboratory clothing worn by the analyst should be clean, since clothing previously exposed to methylene chloride fumes during liquid/liquid extraction procedures can contribute to sample contamination.

3.6 Samples can be contaminated by diffusion of volatile organics (particularly methylene chloride and fluorocarbons) through the septum seal of the sample container into the sample during shipment and storage. A trip blank prepared from organic-free reagent water and carried through the sampling, handling, and storage protocols can serve as a check on such contamination.

3.7 Use of sensitive mass spectrometers to achieve lower detection level will increase the potential to detect laboratory contaminants as interferences.

3.8 Direct injection - Some contamination may be eliminated by baking out the column between analyses. Changing the injector liner will reduce the potential for cross-contamination. A portion of the analytical column may need to be removed in the case of extreme contamination. The use of direct injection will result in the need for more frequent instrument maintenance.

3.9 If hexadecane is added to waste samples or petroleum samples that are analyzed, some chromatographic peaks will elute after the target analytes. The oven temperature program must include a post-analysis bake out period to ensure that semivolatile hydrocarbons are volatilized.

B-2. VOC ANALYSIS RESULTS (NSA PANAMA CITY)

B3. VOC ANALYSIS RESULTS (NTC ORLAND)

B-4. GRAIN SIZE ANALYSIS SUMMARY

The grain size samples will be analyzed according to Plumb (1981). Sediment samples will be wet-sieved through a No. 230 (0.0625 mm) U.S. Standard sieve. The fine fraction (silt and clay) will be collected in a 1-L graduated cylinder. Sediment retained on the No. 230 sieve will be washed with distilled water into labeled, pre-weighted beakers and oven-dried for 24 hours at 105 °C. After drying, the sediment will be sieved through a series of nested sieves to determine the percent gravel, very coarse sand, coarse sand, medium sand, fine sand, and very fine sand. Sediment passing the No. 230 sieve will be added to the fine fraction in the graduated cylinder. The fine fraction will be stirred and aliquots secured (pipette analysis) to determine the distribution of fines and to calculate the percent silt (0.0625 to 0.0039 mm) and clay (<0.005 mm). Quality control will consist of duplicate analysis with each batch of 20 or fewer samples. The resulting relative percent difference should be less than 25% for gravel, sand, silt, and clay fractions.

B-5. TOC ANALYSIS BY U.S. EPA 9060—SUMMARY

Total organic carbon (TOC) analyses will follow the procedures described in EPA 9060 or Kahn. Sample preparation consists of drying, homogenization, and acidification to remove carbonates and bicarbonates. The samples will be combusted in a high-temperature furnace in a stream of oxygen to form CO₂. Interfering gases, such as halogens, sulfur, nitrogen oxides, and water are removed by chemical scrubbers prior to CO₂ measurement.

Coulometer calibration is monitored weekly through the analysis of carbon standards to establish a 4-point calibration curve. The standards include MESS-3 (2% carbon), NIST SRM 1941a (4.8% carbon), a LECO calcium carbonate standard (12% carbon), and a LECO sucrose standard (42.1% carbon). The results must be within 5% RPD of accepted values for sample analysis to proceed. The samples will be analyzed in batches of 20 or fewer field samples. QC samples associated with each batch include a sample duplicate, standard reference material, and instrument blank.

APPENDIX C1

QUALITY ASSURANCE PROJECT PLAN

FOR NSA PANAMA CITY

C1.1 PURPOSE AND SCOPE

The Quality Assurance Plan (QAP) for this demonstration specifies procedures that will be used to ensure data quality and integrity for the Trident probe/UltraSeep demonstration at NSA Panama City. Careful adherence to these procedures will ensure that data generated from the demonstration will meet the desired performance objectives and will yield appropriate analytical results. The content of this QAP is based on guidance provided by ESTCP (2004) and U.S. EPA (1998, 2001). The format approximately follows the format provided in the ESTCP guidance (ESTCP 2004); however, additional information is also included.

To collect performance data of known quality, sampling and analysis procedures are critical. Approved QA/QC procedures must be implemented throughout the evaluation. All staff members participating in the Trident probe/UltraSeep demonstration are required to read this QAP, and must keep it in their possession during field activities. All demonstration participants are required to comply with the procedures identified in this QAP in order to determine that the data collected are of known and documented quality, and are useful for the purposes for which they were collected.

C1.2 QUALITY ASSURANCE RESPONSIBILITIES

A well-organized project team, combined with adequate experience and proper training, will ensure consistent quality throughout the Trident probe/UltraSeep demonstration. Section 8 of this report provides points of contact and project roles, while the organization of demonstration team members is shown in Figure C1-1.

Primary responsibility for execution of the demonstration will be taken by Bart Chadwick, SPAWAR Systems Center San Diego (SSC San Diego), and Amy Hawkins, Naval facilities Engineering Service Center (NFESC). The primary site representatives are Philip Mcginnis and Dan Waddill, Engineering Field Division South (EFD South). Primary responsibility for regulatory technical review will be with Bruce Labelle, California Environmental Protection Agency (Cal/EPA). QA officer for the project will be Joel Guerrero (SSC San Diego) who will coordinate all QA activities with site and laboratory personnel.

C1.2.1 Project Description

The overall objective of this project is to field demonstrate and evaluate the effectiveness of two technologies for characterizing coastal contaminant migration. The technologies include recently commercialized versions of a screening probe for determining where groundwater may be discharging, and an integrated seepage meter and water sampling system for quantifying discharge rates and chemical loading.

The Trident probe is a combined conductivity sensor, porewater sampler, and temperature sensor system that utilizes salinity, temperature, and chemical contrasts between groundwater and surface water to map areas of potential groundwater discharge. The UltraSeep is an integrated ultrasonic seepage meter and water sampling system for quantifying discharge rates and chemical loading from groundwater flow to coastal waters.

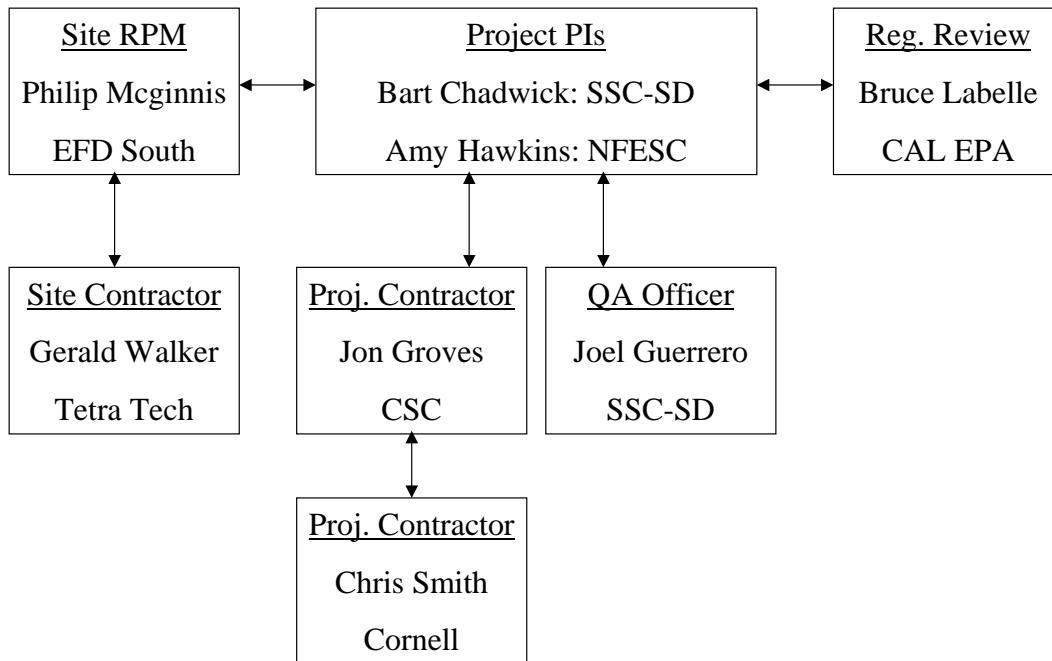


Figure C1-1. Organization of NSA Panama City demonstration team.

The purpose of this demonstration is to perform a full-scale technology evaluation in the field using the Trident probe and the UltraSeep. The technologies will be demonstrated in offshore areas adjacent to known historical landfills or hazardous waste sites where documented evidence exists of potential contaminant migration to the surface water. The demonstration will be performed at two locations: Naval Support Activity (NSA) Panama City, Florida, and a second site to be determined. The primary contaminant of concern at Area of Concern (AOC 1) NSA Panama City is 1,1-DCE, which has been detected at concentrations exceeding the surface water cleanup target level along the shoreline of St Andrews Bay at 10 to 30 ft below ground surface. Based on site conditions, it is uncertain whether the 1,1-DCE is entering the bay.

The specific objectives of this field effort are to accomplish the following:

1. Demonstrate that the Trident probe can be used to help delineate areas where groundwater seepage is occurring
2. Demonstrate that the UltraSeep system can be used to quantify the flow of groundwater and concentration of contaminants that may be impinging on the surface water system
3. Demonstrate the technology to end-users to determine the utility of these tools for making decisions at DoD coastal landfills and hazardous waste sites
4. Quantify costs associated with the operation of each of the technologies

Sampling objectives will be achieved based on the documented performance of the Trident probe and UltraSeep systems at the demonstration site compared to the qualitative and quantitative criteria specified in this plan (Section 3)

C1.2.2 Data Types and Uses

A number of different data types will be collected as part of the Trident probe/UltraSeep demonstration project (Table C1-1 through C1-4). The data types are targeted for the same general purpose, which is to meet the objectives described above, but may have different specific uses with the project framework described in Subsections C1.2.2.1 through C1.2.2.6.

C1.2.2.1 Trident Probe Subsurface Temperature/Conductivity Contrast

Horizontal Trident probe mapping of conductivity and temperature contrast at the groundwater–surface water interface in St. Andrew Bay will be used to identify likely areas of groundwater discharge to St. Andrews Bay. It is expected that during the summer, the groundwater will be colder and fresher than the surface water. Thus, areas in the sediment having these interstitial water characteristics will be identified as likely areas of groundwater discharge. If no areas of temperature/conductivity contrast can be identified, then it will be concluded that the point of discharge is too diffuse to be isolated.

C1.2.2.2 Trident Probe Subsurface VOC Water Sampling

Horizontal Trident probe mapping of VOCs at the groundwater–surface water interface in St. Andrew Bay will be used to identify potential environmental risk relative to media protection standards and to determine the extent of natural attenuation between the shoreline wells and the point of release to St. Andrews Bay. If Trident probe subsurface VOC samples are below the SWCTL, then it will be concluded that natural processes are attenuating the VOC plume such that no risk to the environment exists. If Trident probe subsurface VOC samples exceed the SWCTL, then it will be concluded that potential risk to the environment is present, and UltraSeep water samples will be collected to determine the actual concentration and mass loading of VOCs discharging to the bay.

C1.2.2.3 UltraSeep Groundwater Discharge Quantification

Continuous UltraSeep discharge measurements of groundwater to St. Andrews Bay over a complete tidal cycle will be used to quantify the mean and tidal components of the discharge rate. A positive mean discharge rate is an indicator that groundwater may be carrying VOCs to the bay at that location. The strength of the tidal component of the discharge will be used to assess the degree of detected, it will

C1.2.2.4 UltraSeep VOC Discharge Quantification

Flow-proportional UltraSeep sampling of groundwater discharge to St. Andrews Bay is used to determine the concentration and mass of VOCs discharging to the bay. If UltraSeep VOC discharge concentrations are below the SWCTL, then it will be concluded that natural processes are attenuating the VOC plume such that no risk to the environment exists. If UltraSeep VOC discharge concentrations exceed the SWCTL, then it will be concluded that potential risk to the environment is present and surface water concentrations will be measured to determine the extent of the risk.

C1.2.2.5 Quantification of Surface Water VOCs

Measurement of surface water concentrations of VOCs in St. Andrews Bay will be used to determine if groundwater discharge from AOC 1 is leading to detectable increases in surface water concentrations for VOCs. If Trident probe and UltraSeep data indicate significant VOC discharge to surface water, surface water concentrations will be used to determine the extent of potential risk to the environment. If Trident probe and UltraSeep

data indicate limited or no discharge of VOCs, surface water concentrations will be used to validate the absence of risk.

C1.2.2.6 Piezometer Water Levels and VOCs

Water levels and VOC concentrations in piezometers installed at a subset of stations will be used to validate the Trident probe/UltraSeep results. Because the Trident probe/UltraSeep are new technologies, it is important to provide an independent validation of the results using a previously accepted technology. If the water levels in the piezometers indicate a positive vertical hydraulic gradient in the piezometers would validate a measured positive discharge rate in the UltraSeep. Presence or absence of VOCs in the groundwater sampled will serve as verification of the Trident probe/UltraSeep VOC sample results.

Table C1-1. Trident probe sensor parameters.

Parameter
Sub-surface sediment temperature
Sub-surface sediment conductivity
Surface water temperature
Surface water conductivity

Table C1-2. Trident probe water quality sample parameters.

Parameter
Sub-surface groundwater temperature
Sub-surface groundwater conductivity
Surface water temperature
Surface water conductivity

Table C1-3. UltraSeep sensor parameters

Parameter
Discharge flow rate
Funnel water temperature
Funnel water conductivity

Table C1-4. Trident probe sub-surface and surface water and UltraSeep discharge sample VOC analytes, method detection limits, and reporting limits.

	MDLs for EPA 8260B	Instrument IDs: VOA-1B & VOA-2	Matrix: Water
		Reporting Limit	MDL
	Compound Name	(ppb)	(ppb)
1	1,1,1,2-Tetrachloroethane	1	0.16
2	1,1,1-Trichloroethane	1	0.15
3	1,1,2,2-Tetrachloroethane	1	0.20
4	1,1,2-Trichloroethane	1	0.22
5	1,1-Dichloroethane	1	0.13
6	1,1-Dichloroethene	1	0.18
7	1,1-Dichloropropene	1	0.18
8	1,2,3-Trichlorobenzene	1	0.29
9	1,2,3-Trichloropropane	1	0.22
10	1,2,4-Trichlorobenzene	1	0.25
11	1,2,4-Trimethylbenzene	1	0.14
12	1,2-Dibromo-3-chloropropane	2	0.83
13	1,2-Dibromoethane	1	0.15
14	1,2-Dichlorobenzene	1	0.15
15	1,2-Dichloroethane	1	0.18
16	1,2-Dichloropropane	1	0.13
17	1,3,5-Trimethylbenzene	1	0.16
18	1,3-Dichlorobenzene	1	0.15
19	1,3-Dichloropropane	1	0.21
20	1,4-Dichlorobenzene	1	0.12
21	2,2-Dichloropropane	1	0.17
22	2-Butanone (MEK)	5	2.6
23	2-Chlorotoluene	1	0.14
24	2-Hexanone	2	1.4
25	4-Chlorotoluene	1	0.15
26	Acetone	5	4.08
27	Benzene	1	0.14
28	Bromobenzene	1	0.11
29	Bromochloromethane	1	0.21
30	Bromodichloromethane	1	0.19
31	Bromoform	1	0.24
32	Bromomethane	2	0.57
33	Carbon Disulfide	2	0.28
34	Carbon Tetrachloride	1	0.14
35	Chlorobenzene	1	0.10

Table C1-4. Trident probe sub-surface and UltraSeep discharge sample VOC analytes, method of detection limits, and reporting limits (continued).

	MDLs for EPA 8260B	Instrument IDs: VOA-1B & VOA-2	Matrix: Water
		Reporting Limit	MDL
	Compound Name	(ppb)	(ppb)
36	Chloroethane	1	0.3
37	Chloroform	1	0.15
38	Chloromethane	1	0.19
39	cis-1,2-Dichloroethene	1	0.22
40	cis-1,3-Dichloropropene	1	0.17
41	Dibromochloromethane	1	0.17
42	Dibromomethane	1	0.17
43	Dichlorodifluoromethane	1	0.38
44	Ethylbenzene	1	0.11
45	Hexachlorobutadiene	1	0.25
46	Isopropylbenzene	1	0.11
47	m,p-Xylenes	2	0.24
48	Methyl isobutyl ketone (MIBK)	2	1.24
49	Methyl tert-butyl ether (MTBE)	1	0.33
50	Methylene chloride (DCM)	1	0.16
51	Naphthalene	3	0.79
52	n-Butylbenzene	1	0.26
53	n-Propylbenzene	1	0.13
54	o-Xylene	1	0.15
55	p-Isopropyltoluene	1	0.13
56	sec-Butylbenzene	1	0.15
57	Styrene	1	0.15
58	tert-Butylbenzene	1	0.14
59	Tetrachloroethene	1	0.18
60	Toluene	1	0.14
61	trans-1,2-Dichloroethene	1	0.18
62	trans-1,3-Dichloropropene	1	0.21
63	Trichloroethene	1	0.17
64	Trichlorofluoromethane	1	0.12
65	Vinyl Chloride	1	0.18
66	tert-Butyl Alcohol (TBA)	5	0.99
67	Di-Isopropyl Ether (DIPE)	1	0.44
68	Ethyl tertiary butyl ether (ETBE)	1	0.58
69	Tertiary amyl methyl ether (TAME)	1	0.59

C1.3 DATA QUALITY REQUIREMENTS

The QA objective of this field investigation is to obtain results that are of known and acceptable quality and are representative of the conditions present at the site. The sampling plan for the Trident probe /UltraSeep demonstration has been developed to ensure the collection of sufficient samples from appropriate locations to achieve the goals described in the DQOs. Field sampling procedures will include safeguards to ensure that the samples provided to the laboratories are intact and representative of field conditions.

Measurement quality objectives (MQOs) have been established for this project to ensure that the collected data are of known and sufficiently high quality to support the project objectives. Quantitative MQOs are described in Subsections C1.3.1 through C1.3.6 and in Tables C1-5 and C1-6, including requirements for precision, accuracy, representativeness, completeness, and/or comparability (PARCC).

C1.3.1 Precision

Precision is the reproducibility of measurements of the same characteristic, usually under a specific set of conditions. For replicate measurements, precision is expressed as the relative percent difference (RPD) or the standard deviation (SD), or the relative standard deviation (RSD). Precision for the Trident probe and UltraSeep sensors, including temperature and conductivity, will be assessed on the basis of SDs calculated from replicate analysis performed under controlled laboratory conditions. Sensor replicates will consist of a minimum of 10 individual measurements at the same station. For the Trident probe and UltraSeep VOC analysis, precision will be assessed on the basis of RPDs calculated from replicate analysis of samples collected at a subset of stations in the field (minimum of 1 out of each 10 stations).

C1.3.2 Accuracy

Accuracy is the degree to which a measurement agrees with the true value. For Trident probe and UltraSeep sensors, accuracy will be assessed on the basis of sensor readings in controlled laboratory conditions. Known conditions for the conductivity sensor will be achieved using National Institute of Standards and Technology (NIST)-certified standards and validated using a laboratory conductivity cell. Known conditions for temperature will be achieved using a temperature bath and validated using a highly accurate, calibrated digital oceanographic thermometer. Analytical accuracy for the Trident probe and UltraSeep VOC samples will be assessed on the basis of matrix spike matrix spike duplicate (MS/MSD) samples. MS/MSD samples or blank spike samples are analyzed at a frequency of 1 for every 20 samples. Accuracy is expressed in terms of percent recovery.

C1.3.3 Representativeness

Representativeness is a qualitative expression of the degree to which sample data accurately represent the characteristics of a population, parameter variations at a sampling point, or an environmental condition that they are intended to represent. Representativeness is maximized by (1) selecting the appropriate number of samples and sampling locations, and (2) using appropriate and established sample collection, handling, and analysis techniques to provide information that reflects actual site conditions.

C1.3.4 Completeness

Completeness assesses the amount of valid data obtained from a measurement system. The percent completeness is calculated by the number of samples yielding acceptable data divided

by the total number of samples planned to be collected and multiplied by 100. The data validation process will determine whether a particular data point is valid and acceptable, estimated and acceptable, or rejected and unacceptable. Complete results are considered acceptable and usable when they are valid or estimated. Sampling results that are considered rejected and unacceptable are considered incomplete. For the Trident probe sensors, the objective for the degree of completeness is 90 percent of those stations where direct-push operations are feasible. For the UltraSeep sensors, the objective for the degree of completeness is 90 percent of the operating duration of the deployment. For the Trident probe and UltraSeep VOC samples, the objective for the degree of completeness is 95 percent of the samples that are successfully obtained using the systems.

C1.3.5 Comparability

Comparability is a qualitative parameter that expresses the degree of confidence that one data set may be compared to another. This goal is achieved through the use of (1) standardized techniques to collect and analyze samples, and (2) appropriate units to report analytical results. The comparability of the data will be maximized by using standard analytical methods when possible, reporting data in consistent units, reporting data in a tabular format, and validating the results against commonly accepted methodologies.

Table C1-5. Measurement quality objectives for Trident probe and UltraSeep sensors.

Parameter	Range	Accuracy	Precision
Trident probe Temperature	-5 to +45 °C	±0.1 °C	0.05 °C
Trident probe Conductivity	0 to 80 mS/cm	±2% FS	2 mS/cm
UltraSeep flow	0-50 cm/d	1 cm/d	0.5 cm/d
UltraSeep Temperature	-5 to +45 °C	±0.1 °C	0.05 °C
UltraSeep Conductivity	0 to 80 mS/cm	±2% FS	2 mS/cm

Table C1-6. Measurement quality objectives for VOC analysis.

Chemical Analysis	Method Reference	Units	Method Reporting Limit	Bias (%)	Precision (RPD)	Completeness (%)
VOCs	EPA 8260B	g/L	1 to 5	70–130	±30	95

C1.3.6 Documents and Records

Procedures, observations, and test results will be documented for all sample collection, laboratory analysis and reporting, and data validation activities. In addition to data reports provided by the laboratories, reports will be prepared that address data quality and usability, provide tabulated laboratory and field data, and interpret the Trident probe/UltraSeep data.

C1.3.6.1 Field Records

Field records will be maintained during all stages of sample collection and preparation for shipment to the laboratory. Field records will include the following:

- Field logbook to record daily sampling activities, conditions, and locations
- Sample labels
- Combined chain-of-custody/sample analysis request (COC/SAR) forms
- Custody seals to monitor collar security during shipment
- Photographic equipment

C1.3.6.2 Laboratory Data Reports

The laboratory will perform data reduction as described in each test method for this project, and submit a complete data package with full documentation for all analyses. The laboratory quality assurance officer is responsible for reviewing laboratory data packages and checking data reduction prior to submittal. The laboratory will provide all information required for a complete quality assurance review, including the following:

- A cover letter describing analytical procedures and methods that were followed and any problems that were encountered during the analyses
- A summary of analyte concentrations and method reporting limits
- Laboratory data qualifier codes appended to analyte concentrations and a summary of code definitions
- Initial and continuing calibration data, including instrument printouts and quantification summaries for all analytes
- Results for method and calibration blanks
- Results for all QA/QC checks, including laboratory control samples, matrix spike samples, surrogate spikes, duplicate matrix spike samples, and laboratory duplicate or triplicate samples
- Original data quantification reports for all analyses and samples

C1.3.6.3 Data Quality and Usability

A data quality and usability analysis will be performed with the Trident probe/UltraSeep demonstration. The analysis will summarize the results of the data validation and data quality review, and will describe any significant quality assurance problems that were encountered. All data and any qualifiers applied to the data as a result of the quality assurance review will be included in the final report.

C1.4 DEMONSTRATION PROCEDURES

C1.4.1 Sampling Design

The sampling program is divided into two phases. In phase 1, the Trident probe will be used to map the horizontal distribution of temperature contrast, conductivity contrast, sub-surface VOCs, and surface water VOCs. Based on the results from the Trident probe survey, stations will be selected for UltraSeep deployment. The UltraSeep will then be used to quantify the discharge rate of groundwater to surface water, and the VOC concentration in the discharge water. Both phases will include parallel sampling with piezometers as a method of comparative validation of the new Trident probe/UltraSeep technologies.

Validation sampling using piezometers will occur along the six central transect stations (T3), and at the three UltraSeep/surface waters sampling stations. For the Trident probe

validation, piezometers will be installed 2 ft below the sediment surface. The 2-ft piezometer will be used to collect water samples for validation of the Trident probe results. Water samples from the 2-ft piezometer will be collected at the same time the corresponding Trident probe water sample is collected.

For the UltraSeep validation, piezometers will be installed 1 and 3 ft below the sediment surface. The 1-ft piezometers will be used to evaluate the near-surface VOC concentrations that would be discharging to the bay for comparison to discharge samples collected by the UltraSeep. Water levels from the 3-ft piezometers will be recorded on a periodic basis throughout the tidal cycle to determine the vertical hydraulic gradient as a means of validating the UltraSeep direct flow measurements.

C1.4.2 Sampling Methods

C1.4.2.1 Trident Probe Sub-Surface and Surface Water Sampling

Thirty Trident probe stations will be sampled for temperature/conductivity contrast and sub-surface and surface VOC water sampling. Trident probe sampling locations are located along five offshore transects extending eastward from the shoreline with six stations each. Alongshore and offshore sample spacing is approximately 100 ft. Trident probe sub-surface temperature/conductivity and VOC sampling will be performed at approximately 2 ft below the sediment surface, depending on the practical penetration depth of the probe. Surface water will be collected from the water column approximately 1 ft above the sediment surface. Trident probe sampling will be timed to occur during the falling tide, when discharge conditions are most favorable. Sampling procedures for the Trident probe are described in detail in the system documentation and operating manuals (Chadwick et al., 2003b; Appendix A). Sample preservation and holding time requirements are shown in Table C1-7.

Table C1-7. Sample preservation and holding time requirements.

Analyte	Sample Size	Container	Preservation and Handling	Maximum Holding Time
VOCs	2 x 40 ml	40-ml VOC vial with Teflon®-lined septum.	1:1 HCl to pH<2; Cool to 4 ±2 °C	14 days

At each station, the following general procedure will be used:

- Occupy the sampling station using the Trident probe GPS unit or using a previously deployed marker buoy
- Secure the sampling platform using lines or anchors as necessary to minimize movement during the sampling operation
- Lower the probe tips to within 1 ft of the sediment surface and hold while temperature and conductivity readings stabilize
- Record position, temperature and conductivity readings to the Trident probe laptop
- Collect the surface water sample using the water sampler on the Trident probe (see details below)
- Push the Trident probe into the sediment to the 2 ft measurement depth (set stopper plate accordingly) and hold while temperature and conductivity readings stabilize

- Record position, temperature and conductivity readings to the Trident probe laptop
- Collect the sub-surface groundwater sample using the water sampler on the Trident probe (see details below)
- Decontaminate the Trident probe water sampler and the ancillary water sampling equipment
- If the station is a validation station, purge the piezometer and collect the sub-surface groundwater sample using the piezometer (see validation sampling details below)
- Decontaminate the ancillary water sampling equipment
- Move to the next station and repeat the operation

During surface water sample collection, surface water samples for VOC analysis will be collected using the water sampling probe on the Trident probe connected by 1/16-inch inside diameter Teflon® tubing to an in-line VOA bottle filler (Solinst, Inc.) powered by a low-flow peristaltic pumping system. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) will be pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994.

The probe is held at depth of 1 ft above the sediment surface using the push-pole system. A Y-valve is used to direct the sample water first to a purging syringe, and then to the sampling system. The purging syringe is used to withdraw approximately 60 ml (an estimated three sampler volumes, assuming a 10-m sample tube), and the sample system is then used to fill two 40 ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential (ORP), and total dissolved solids [TDS]). The VOA bottles are pre-cleaned, amber glass, 40 ml, pre-acidified (pH 2), screw cap vials with Polytetrafluoroethylene (PTFE)-faced silicone septa.

During subsurface groundwater sample collection, groundwater for VOC analysis will be collected using the water sampling probe on the Trident probe connected by 1/16-inch inside diameter Teflon® tubing to an in-line VOA bottle filler (Solinst, Inc.) powered by a low-flow peristaltic pumping system. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) will be pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA, 1996.

The probe is inserted to a depth of 2 ft below the sediment surface using the push-pole system. A Y-valve is used to direct the sample water first to a purging syringe, and then to the sampling system. The purging syringe is used to withdraw approximately 60 ml (an estimated three sampler volumes assuming a 10-m sample tube), and the sample system is then used to fill two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter (Myron L Company) water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential, and total dissolved solids). The VOA bottles are pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw cap vials with PTFE-faced silicone septa.

C1.4.2.2 UltraSeep Sampling

A minimum of three UltraSeep stations will be sampled for specific discharge, VOC discharge, and temperature/conductivity of the discharge. Sampling locations for the UltraSeep will be selected in consultation with the site manager based on the results of the Trident probe survey. The locations will be selected to target areas of highest potential water

and VOC discharge. UltraSeep measurements will extend over a complete diurnal tidal cycle. UltraSeep water samples will be collected approximately every 2.5 hours depending on discharge conditions. Sampling procedures for the UltraSeep are described in detail in the system documentation and operating manuals (Chadwick et al., 2003b; Appendix A). Sample preservation and holding time requirements are shown in Table C7. At each station, the following general procedure will be used:

- Occupy the sampling station using the a GPS unit or using a previously deployed marker buoy
- Deploy the UltraSeep by diving or wading depending on water depth
- Assure that the funnel knife edge is completely sealed into the sediment
- Assure that any air that may have been trapped in the funnel or the flow tube has been purged
- Zero the flow meter
- Start the UltraSeep system, allowing a 1-2 hour period prior to the collection of any discharge samples to allow the system to equilibrate following any flow disturbance that may have been caused by the deployment process
- Allow the sensor system and water sampler to run for the full tidal cycle (see water sampling details below)
- Regularly check the flow meter readings and bag filling to assure that the system is functioning properly
- Collect validation samples from the 1 ft piezometers during periods when discharge is noted from the flow meter (see validation sampling details below)
- Retrieve the system and return to the shore facility
- Decontaminate the system
- Redeploy to the next station and repeat the procedure

Discharge water samples for VOC analysis will be collected using the water sampling system on the UltraSeep. The system draws samples from the seepage funnel to the Teflon® sampling bags via a 1/16-inch inside diameter Teflon® tube using the built-in peristaltic pump. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) will be pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994.

The UltraSeep is deployed on the bottom and up to 10 water samples are collected at an interval of about 2.5 hours in proportion to the measured discharge rate. The entire deployment period is about 25 hours. Following retrieval of the UltraSeep, the water samples are transferred from the sampling bags to two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, ORP, and TDS). The VOA bottles are pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw-cap vials with PTFE-faced silicone septa.

C1.4.2.3 Validation Sampling

Validation sampling using piezometers will occur along the six central transect stations (T3), and at the three UltraSeep/surface waters sampling stations. For the Trident probe validation, piezometers will be installed 2 ft below the sediment surface. The 2-ft piezometer will be used to collect water samples for validation of the Trident probe results. Water

samples from the 2-ft piezometer will be collected at the same time the corresponding Trident probe water sample is collected.

For the UltraSeep validation, piezometers will be installed 1 and 3 ft below the sediment surface. The 1-ft piezometers will be used to evaluate the near-surface VOC concentrations that would be discharging to the bay for comparison to discharge samples collected by the UltraSeep. Water levels from the 3-ft piezometers will be recorded on a periodic basis throughout the tidal cycle to determine the vertical hydraulic gradient as a means of validating UltraSeep direct flow measurements.

C1.4.2.4 Sub-Surface Groundwater Validation Water Samples

Validation groundwater samples for VOC analysis will be collected using stainless-steel drive-point piezometers ½-inch inside diameter Teflon® tubing to an in-line VOA bottle filler (Solinist, Inc.) powered by a low-flow peristaltic pumping system. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) will be pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994.

The piezometer is driven to a depth of 2 ft (Trident probe validation) or 1 ft (UltraSeep validation) below the sediment surface using either a slide hammer or rotary hammer system. The piezometer is developed using the low-flow pump and the piezometer is allowed to re-equilibrate with the groundwater. The sample system is then used to fill two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, oxidation reduction potential [ORP], and total dissolved solids [TDS]). The VOA bottles are pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw-cap vials with PTFE-faced silicone septa.

C1.5 SAMPLE HANDLING AND CUSTODY

Documentation during sampling activities is essential to ensure proper sample identification, integrity, and custody. A description of standard sample custody procedures that will be used to maintain and document sample integrity during collection, transportation, storage, and analysis is provided in Subsections C1.5.1 through C1.5.5.

C1.5.1 Sample Custody Procedures

The field team will follow standard EPA chain-of-custody procedures for each sample as it is collected. Until shipped to the laboratory, the samples will be retained at all times in the field crew's custody. A sample is considered to be in custody if one of the following statements applies:

- It is in a person's physical possession or view.
- It is in a secure area with restricted access.
- It is placed in a container and secured with an official seal such that the sample cannot be reached without breaking the seal.

The quality assurance officer is responsible for ensuring proper sample handling and documentation that will allow tracking the possession and handling of individual samples from the time of collection to laboratory receipt. The laboratory QC manager is responsible for establishing a sample control system that will allow tracking sample possession from laboratory receipt to final disposition of the sample.

C1.5.2 Sample Labels

A sample label will be affixed to all sample containers sent to the laboratory. This identification label will be completed with the following information written in indelible ink:

- Project name and location
- Sample location
- Sample identification number
- Date and time of sample collection
- Preservative used
- Sample collector's name and initials
- Filtering (if applicable)
- Type of sample (grab or composite)
- Analysis required

If a sample is split with another party, sample labels with identical information will be attached to each sample container. After labeling, each sample will be refrigerated or placed in a cooler containing ice or “blue ice” to maintain the sample temperature at $4 \pm 2^{\circ}\text{C}$.

C1.5.3 Sample Documentation

Sampling activities during the field effort require several forms of documentation. The documents are prepared to maintain sample identification and chain of custody, and provide records of significant events or observations. In addition, other documents will be prepared, such as field logs.

C1.5.4 Shipping Procedures

All U.S. Department of Transportation regulations will be followed during sample packaging and shipment. Samples will be collected at the end of each of the field study phases. They will be transferred to appropriate laboratory containers, labeled, placed in a chilled ice chest, and shipped overnight to the laboratory.

C.1.5.5 Laboratory Procedures

Upon receipt of a cooler, laboratory personnel will review the contents, and sign and retain the chain-of-custody record and the air bill. Information that will be recorded on the chain-of-custody record or another appropriate document at the time of sample receipt will include the following:

- Status of the custody seals
- Temperature of the cooler upon receipt
- Identification number of any broken sample containers
- Description of discrepancies between the chain-of-custody records, sample labels, and requested analyses
- Storage location of the sample and sample extracts

Laboratory personnel will contact the analytical coordinator regarding discrepancies in paperwork and sample preservation, and will document nonconformance and corrective actions in accordance with laboratory standard operating procedures (SOPs). These procedures will be available on file at the laboratory. After samples have been accepted, checked,

and logged in by the laboratory, they must be maintained in a manner consistent with the custody and security requirements specified in the laboratory QA plan.

All samples and sample extracts will be assigned to a specific refrigerator within the laboratory. All laboratory refrigerators will be assigned a number, and the refrigerator number will be recorded on an appropriate document that references the sample and extract locations. Only laboratory personnel will have access to the samples and will be required to sign a log sheet when removing samples and extracts from the refrigerators or replacing them. These log sheets will provide a chain-of-custody record as the samples move within the laboratory. A chain-of-custody record, similar to the chain-of-custody record used for sampling procedures, will be completed for samples removed from the laboratory for disposal or other purposes.

C1.6 ANALYTICAL METHODS

C1.6.1 VOCs

VOC samples from the Trident probe, UltraSeep, surface water, and validation surveys will all be analyzed following EPA method 8260B at a remote laboratory, or using an on-site mobile laboratory (Appendix B). Details of the method, analytical instrumentation, matrix considerations, concentration units, statistical procedures, and detection limits are all described in U.S. EPA (1996).

C1.6.2 Water Quality

Sub-samples of the Trident probe, UltraSeep, surface water, and validation samples will be analyzed on-site using a Myron model 6b water quality analyzer. The analyzer detects temperature, conductivity, pH, ORP, and TDS. The cell volumes for the measurement are 1.2 ml (pH/ORP) and 5 ml (temperature/conductivity/TDS). Quoted accuracy and precision levels for the meter are shown in Table C1-8. The meter is calibrated to certified NIST standards prior to each survey.

Table C1-8. Specifications for the UltraMeter water quality analyzer.

	Range	Resolution	Accuracy
pH	0 to 14 pH	0.01 pH	0.01 pH
ORP	± 999 mV	± 1 mV	± 1 mV
Conductivity	0 to 9999 µS	0.01 < 100 µS	± 1% of reading
	10 to 200 µS	0.1 < 1000 µS	
	5 autoranges	1.0 > 1000 µS	
TDS	0 to 9999 ppm	0.01 < 100 ppm	± 1% of reading
	10 to 200 ppt	0.1 < 1000 ppm	
	5 autoranges	1.0 > 1000 ppm	
Resistivity	10 KΩ to 30 MΩ	0.01 < 100 KΩ	± 1% of reading
		0.1 < 1000 KΩ	
		0.01 > 1 MΩ	
Temperature	32 to 160F	0.1F	± 0.1F

C1.7 QUALITY CONTROL REQUIREMENTS

Quality control requirements consist of field quality control checks and laboratory quality control checks. Field quality control checks are intended to verify that contamination during field sampling did not occur and the Trident probe and UltraSeep are functioning properly. Laboratory quality control checks are intended to verify that samples were analyzed to an acceptable level of PARCC parameters.

C1.7.1 Field Quality Control Checks

Field quality control checks include equipment rinsate blanks, field duplicates, and trip blanks, which are described in Subsections C2.7.1.1 through C2.7.1.3.

C1.7.1.1 Equipment Rinsate Blanks

Equipment rinsate blanks will be collected for the Trident probe, UltraSeep, and the piezometers used to identify possible contamination associated with the sampling environment or the sampling equipment. These blanks will be collected for the Trident probe by drawing a water sample through the probe from a container of dionized water using the same sampling equipment that is used during normal system operations.

For the UltraSeep, equipment blanks will be collected by (1) pouring deionized water over the funnel into a jar, and (2) pumping water through the UltraSeep onboard sampling system into a Teflon® sampling bag and collecting the blank from the bag.

For the piezometers, rinsate blanks will be collected by placing the piezometer tip into a container of deionized water and drawing a water sample through the piezometer using the same sampling equipment as is used during normal system operations.

C1.7.1.2 Field Duplicates

Field duplicates will be collected to assess the homogeneity of the samples collected in the field, and the overall precision of the sampling process. Field duplicates are automatically collected at every station for the Trident probe and piezometers using the VOA bottle filler.

C1.7.1.3 Trip Blanks

One trip blank for each sample shipment will be collected by placing a sample of deionized water in a sample cooler at the beginning of the demonstration. The trip blank will be a quality control measure to ensure that samples are not contaminated during sample storage and shipment to the laboratory.

C1.7.2 Laboratory Quality Control Checks

Each analytical protocol used in this technology demonstration includes specific instructions for analysis of quality control samples and completion of quality control procedures during sample analysis. Laboratory QC checks are designed to assess the precision and accuracy of the analysis, demonstrate the absence of interferences and contamination from glassware and reagents, and ensure the comparability of data. Laboratory QC checks consist of method blanks, laboratory control samples, laboratory duplicates, MS/MSDs, and surrogates, which are described in Subsections C1.7.2.1 through C1.7.2.5.

C1.7.2.1 Method Blanks

Method blanks are used to verify that preparation of samples was contamination-free. Each batch of extracted and digested samples is accompanied by a blank that is analyzed in parallel

with the rest of the samples, and carried through the entire preparation and analysis procedure. Method blanks for VOCs will be analyzed for every sample preparation group or 1 for every 20 samples, whichever is more frequent.

C1.7.2.2 Laboratory Control Samples

Laboratory control samples (reference material or spiked blanks) are used to check overall method performance. An LCS for VOCs will be analyzed for every sample delivery group or 1 for every 20 samples, whichever is more frequent.

C1.7.2.3 Replicate Laboratory Analyses

Replicate laboratory analyses are indicators of laboratory precision. Laboratory duplicates are analyzed during analysis of water samples analyzed for VOCs by splitting 1 in 20 field samples or one sample from every sample delivery group, whichever is more frequent.

C1.7.2.4 MS/MSDs

MS/MSDs are used to assess the effects of the sample matrix on the accuracy and precision of analytical measurements. MS/MSDs for VOCs will be analyzed for every sample delivery group or 1 for every 20 samples, whichever is more frequent.

C1.7.2.5 Surrogate Spike Compounds

Surrogate spike compounds will be added to all field and quality control samples for VOC analysis to evaluate the recovery of analytes for each sample.

C1.7.3 Instrument and Equipment Maintenance and Calibration Requirements

Subsections C2.7.3.1 through C1.7.3.2 discuss regularly scheduled preventive maintenance and calibration procedures to keep all field and laboratory equipment in good working condition. Generally, the Principal Investigator (PI) will be responsible for ensuring that routine preventative maintenance and calibrations are performed and documented for all field instrumentation and equipment. The laboratory quality assurance officer will be responsible for ensuring that routine maintenance and calibrations are performed and documented for analytical instrumentation.

C1.7.3.1 Field Equipment

Detailed information regarding maintenance and servicing of field equipment is available in the guidance documents and manuals for the specific instrument to be used (Chadwick et al., 2003b; Appendix A). Field personnel will record service and maintenance information in field logs. General guidelines for the maintenance and calibration of the Trident probe and UltraSeep are described in Chadwick et al. (2003b).

The temperature sensors are robust and require little maintenance. The sensor area should be kept clean and free of residues. The sensor should be tested and the calibration checked prior to the demonstration to assure that the precision and accuracy are within manufacturer's specification. If the temperature sensor is out of specification, it can be returned to the manufacturer for recalibration, or recalibrated in the laboratory under closely controlled conditions.

The Trident probe and UltraSeep conductivity sensors are also very robust, but may require more frequent calibration. The sensor area should be kept clean and free of residues. The sensor should be tested and the calibration checked at the beginning and end of each day

of operations. The calibration can be tested by immersing the sensor in a beaker filled with NIST certified conductivity standard and comparing the measured value and replicate standard deviation with the manufacturers specification. If the conductivity sensor is out of specification, it can be calibrated in the laboratory or in the field using NIST certified standards.

The Trident probe water-sampling probe should be visually inspected before and after each sub-surface push. If the filter screen is damaged, the screen should be replaced. A supply of replacement screens should be available during any field deployment that uses the water sampler. The sample tubing should also be inspected for kinking or damage, and repaired or replaced if necessary. The peristaltic pump tubing should also be inspected periodically to ensure that it is not damaged.

The UltraSeep flow sensor should be tested, zeroed and calibrated prior to each demonstration. In addition, the sensor should be re-zeroed following deployment at each station. Calibration of the flow sensor is generally carried out in the laboratory under controlled conditions.

C1.7.3.2 Laboratory Equipment

The analytical laboratory will prepare and follow a maintenance schedule for each instrument used to analyze demonstration samples. All instruments will be serviced at scheduled intervals to optimize factory specifications. Routine preventive maintenance and major repairs will be documented in a maintenance logbook.

Initial and continuing calibration procedures for laboratory equipment and instrumentation will be completed in accordance with the cited analytical method for each analysis. The method descriptions for each analysis specify the acceptance criteria for initial and continuing calibration and state the conditions where recalibration is necessary.

C1.7.4 Data Management

Computerized systems will be used to record, store, sort, and analyze the technical data that will be generated from the Trident probe/UltraSeep demonstration. Automated data handling processes will be utilized that increase data integrity by reducing errors, omissions, and ambiguities that can be introduced by manual procedures. In addition, automated procedures will be used by the analytical laboratory to capture and summarize analytical results. This will also improve efficiency and reduce errors by allowing direct electronic transfer form the laboratory to the project computer systems.

Sensor data from the Trident probe and UltraSeep can also be transferred electronically into the project data system. Information form field logs, claims of custody/sample analysis request (COC/SAR) forms, and other sources will be entered manually into the data system. Each data record will include a unique sample code, station ID, sample type, analyte, analyte concentration, and concentration units. Data qualifiers are entered into the data system once the data validation process is completed.

Project data tables and reports are generated using standardized templates and customized retrievals and filters based on user specified criteria. Standard templates are available for analysis of both the Trident probe and UltraSeep data products. Results from the Trident probe survey are generally transformed into spatial maps using a Geographic Information System, while the UltraSeep results are generally processed as time-series output. Additional details and examples of the data analysis process are described in Chadwick et al.(2003b).

C1.8 PERFORMANCE AND SYSTEM AUDITS

This section describes the types of audits that may be conducted, appropriate corrective action procedures that will be taken if problems occur in the field and the laboratory, and quality assurance reports to management. QA audits evaluate the capability and performance of a measurement system or its components, and identify problems that warrant correction.

Audits may include reviews of project plan adherence; training status; health and safety procedures; activity performance and records; budget status; QC data; calibrations; conformance to SOPs; and compliance with laws, regulations, policies, and procedures. Personnel who are independent of the sampling and analytical teams conduct internal audits. These may be ESTCP or Cal/EPA certification program auditors. Copies of field audit reports will be forwarded to the Trident probe/UltraSeep PI. Subsections C1.8.1 through C1.8.4 This chapter describes laboratory system, performance, and field audits.

C1.8.1 System Audits

System audits include a thorough evaluation of both field and laboratory QC procedures and are normally completed before data are collected. This type of audit may consist of site reviews of measurement systems, including facilities, equipment, and personnel. In addition, measurement, QC, and documentation procedures may be evaluated. System audits are conducted on a regularly scheduled basis; the first audit is conducted shortly after a system becomes operational.

C1.8.2 Performance Audits

A performance audit reviews the existing project and QC data to determine the accuracy of a total measurement system or a component of the system. Performance audits of sampling and analysis procedures will be conducted for field and laboratory activities. The audits may consist of the following, as appropriate:

- Field audit during the demonstration to verify that sampling and monitoring procedures and frequencies specified in the technology evaluation plan are being followed
- Laboratory audit during analysis of evaluation samples to verify that procedures and frequencies specified in the technology evaluation plan are being followed
- Issuance of blind QC samples for analysis of specified critical parameters
- Internal audit routines for the laboratory are described in the laboratory QA plan.

C1.8.3 Field Audits

A field audit involves a site visit by the auditor or auditing team. Items to be examined include the following:

- Availability and implementation of SOPs
- Calibration and operation of equipment
- Packaging, storage, and shipping of samples
- Documentation of on-site procedures and instructions
- Documentation of non-conformances

C1.8.4 Corrective Action Procedures

An effective QA program requires prompt and thorough correction of non-conformance conditions affecting quality. Rapid and effective corrective action minimizes the possibility that questionable data or documentation will be produced.

Two types of corrective actions exist: immediate and long term. Immediate corrective actions include correction of documentation deficiencies or errors, repair of inaccurate instrumentation, or correction of inadequate procedures. Often, the source of the problem is obvious and can be corrected when first observed. Long-term corrective actions are designed to eliminate the sources of problems. Examples of long-term corrective actions are correction of systematic errors in sampling or analysis, and correction of procedures producing questionable results. Corrections can be made through additional personnel training, instrument replacement, or procedural improvements. One or more corrections may be necessary.

All QA problems and corrective actions will be documented to provide a complete record of QA activities and to help identify needed long-term corrective actions. Defined responsibilities are required for scheduling, performing, documenting, and ensuring the effectiveness of the corrective action. Subsection C1.8.4.1 and C1.8.4.2 describe the corrective action procedures to be followed in the field and laboratory.

C1.8.4.1 Field Procedures

Field nonconformance conditions are defined as occurrences or measurements that are unexpected or that do not meet established acceptance criteria and will affect data quality if corrective action is not implemented. Examples of non-conformances include the following:

- Incorrect use of field equipment
- Improper sample collection, preservation, and shipment procedures
- Incomplete field documentation, including chain-of-custody records
- Incorrect decontamination procedures
- Incorrect collection of QC samples

Corrective action procedures will depend on the severity of the nonconformance. In cases where immediate and complete corrective action is implemented by field personnel, the corrective actions will be recorded in the field log.

Non-conformances identified during an audit that have a substantial impact on data quality require the completion of a corrective action request form. This form may be filled out by an auditor or by any individual who suspects that any aspect of data integrity is affected by a field non-conformance. Each form is limited to a single non-conformance; if additional problems are identified, multiple forms will be used for documentation.

In the event that a corrective action is required due to improper field technique, the program manager will be notified. The program manager, program scientist, and the project QA/QC officer will meet to discuss the appropriate steps to resolve the problem, and will use the following list:

- Determine when and how the problem developed
- Assign responsibility for problem investigation and documentation
- Determine the corrective action to eliminate the problem

- Set a schedule for completion of the corrective action
- Assign responsibility for implementing the corrective action
- Document and verify that the corrective action has eliminated the problem
- Include report of the problem and the corrective action taken in final report

A corrective action status report must be used by the project QA/QC officer to monitor the status of all corrective actions. In addition to a brief description of the problem and the individual who identified it, the report will list personnel responsible for determining and implementing the corrective action. The report also will list completion dates for each phase of the corrective action procedure and the due date for the project QA/QC officer to review and check the effectiveness of the solution. Follow-up data also will be listed to check that the problem has not reappeared. The follow-up review is conducted to ensure that the solution has adequately and permanently corrected the problem.

The project QA/QC officer can require data acquisition to be limited or discontinued until the corrective action is complete and the nonconformance is eliminated. The project QA/QC officer can also request re-analysis of any or all data acquired since the system was last in control.

C1.8.4.2 Laboratory Procedures

Internal laboratory corrective action procedures and a description of out-of-control situations requiring corrective action are contained in the laboratory QA plan. At a minimum, corrective action will be implemented when any of the following three conditions occur: control chart warning or control limits are exceeded; method QC requirements are not met; or sample holding times are exceeded. Out-of-control situations will be reported to the program manager within 2 working days of identification. In addition, a corrective action report, signed by the laboratory director or project managers and the laboratory QC coordinator, will be provided to the program manager.

C1.9 DATA REVIEW, VALIDATION, AND VERIFICATION

Correct equations and procedures must be used to ensure that all laboratory data generated and processed are scientifically valid, defensible, and comparable. The following sections describe the data review, validation, verification, and reporting procedures that will be used in this evaluation.

C1.9.1 Data Review

Each analytical method contains detailed instructions and equations for calculating compound concentrations or parameters. Data will be reduced using the procedures given in the analytical methods. Final data presentation will be checked for compliance with data documentation requirements, and will be approved and certified by the laboratory senior officer. In general, data package requirements include but are not limited to the following categories:

- Custody of sample
- Performance of instruments
- Identification and quantitation of parameters
- Integrity, precision, and accuracy (QC checks) of samples

Field data recorded during sampling will be reduced to tables for review and verification. After they have been verified, the data will be compiled and reported in summary tables and figures, as appropriate. Corresponding descriptions and units of measure will also be provided to accurately reflect field conditions.

The analysts responsible for the measurements will enter raw data into logs or on data sheets. In accordance with standard document control procedures, the laboratory will maintain on file the original copies of all data sheets and logs containing raw data, signed and dated by the responsible analyst. Separate instrument logs will also be maintained by the laboratory to enable run sequences to be reconstructed for individual instruments.

C1.9.2 Data Validation and Verification

Data validation is a systematic process of reviewing and qualifying data against a set of criteria to determine that the data are adequate for their intended use. During the validation process, all results will be identified as (1) acceptable for use, (2) estimated and acceptable for limited use, or (3) rejected and unacceptable for use. Results considered rejected will be retained in the database but will not be used in quantitative evaluations. Estimated and rejected data can result from improper sampling or analytical methodology, matrix interferences, errors in data transcription, and changes in instrument performance. Erroneous results found during data validation will be identified and corrected.

C1.9.2.2 Field Validation and Verification

Field personnel will review field data to identify inconsistencies or anomalous values in accordance with the MQOs for the field equipment and instrumentation. Any inconsistencies discovered will be resolved immediately, if possible, by seeking clarification from the personnel responsible for collecting data. All field personnel will be responsible for following the sampling and documentation procedures described in the demonstration plan and the QAP in order to assure that defensible and justifiable data are obtained. Specific requirements for field sampling include but are not limited to the following:

- Sampling locations must be fully documented and correct. Errors in sampling location (e.g. as a result of GPS failure) may result in the rejection of data for the subject station.
- Sample collection procedures must be completed as planned and fully documented. Deviations from designated procedures may affect the representativeness of the samples and must be minimized and documented where they occur.
- Sample shipping and handling procedures must be completed as described in the Demonstration Plan and the QAP, in particular the maintenance of sample integrity and proper temperature.
- Results of the field sensor tests and field quality control samples should meet MQO limits.
- Failure to meet these requirements may result in the qualification or rejection of data during the data validation process.

C1.9.2.3 Laboratory Validation and Verification

During analysis and reporting, laboratory personnel will assess data by reviewing raw data for any nonconformance in analytical method protocols. The laboratory QA plan describes detailed procedures for laboratory validation and corrective action. The laboratory QA plan

also discusses sample control, methods of analysis, calibration procedures, document control, QC, corrective actions, QC checks, QA, and data review.

Validation will be completed on data packages for analysis of the water samples. The data reviewer is required to notify the PI of any missing information and request it from the laboratory. Data may not be eliminated from the review process. All data will continue through the validation process and be qualified and requalified as many times as necessary to meet the established criteria.

Full data validation will be required on approximately 10 percent of a sample data group. Data packages consist of sample results, QA/QC summaries, and a review of all raw data associated with the sample results and QA/QC summaries. Data may be qualified as estimated or rejected if any of the following quality control samples and procedures do not meet control limits:

- Sample holding times
- Method of analysis
- Initial and continuing instrument calibration
- Calibration and method blanks
- Laboratory control samples
- Matrix spike and matrix spike duplicate samples
- Surrogate recovery
- Analyte identification and quantification

Project personnel will review the data validation reports from the laboratory to (1) assess whether data quality indicators for chemical measurement were met, and (2) determine whether the data are usable for their intended purpose. The laboratory project manager and the project QA/QC officer will approve the completed laboratory report before it is used to prepare the Trident probe/UltraSeep demonstration report.

C1.9.3 Reconciliation with Data Quality Objectives

The goal of data validation is to determine the quality of the data and to identify data that do not meet the project MQOs. Non-conforming data may be qualified as estimated or rejected as unusable. Rejected data will not be used for any purpose within the context of the demonstration except to guide recommendations for future corrective actions.

If the rejected data are needed to complete the demonstration or to make a decision at the site, it may be necessary to resample. Any decision to resample will be based on discussions among the project team. Data qualified as estimated will be used for the demonstration. These data may be less accurate or precise than unqualified data. The PI and the data users are responsible for assessing the potential ramifications of the inaccuracy or imprecision associated with the qualified data.

APPENDIX C2

QUALITY ASSURANCE PROJECT PLAN

FOR NTC ORLANDO

C2.1 PURPOSE AND SCOPE OF THE PLAN

The Quality Assurance Plan (QAP) for this demonstration specifies procedures that will be used to ensure data quality and integrity for the Trident probe/UltraSeep demonstration at Naval Training Center (NTC) Orlando. Careful adherence to these procedures will ensure that data generated from the demonstration will meet the desired performance objectives and will yield appropriate analytical results. The content of this QAP is based on guidance provided by ESTCP (ESTCP, 2004) and U.S. EPA (U.S.EPA, 1998; 2001). The format approximately follows the format provided in the ESTCP guidance (ESTCP, 2004); however, additional information is also included.

To collect performance data of known quality, sampling and analysis procedures are critical. Approved QA/quality control (QC) procedures must be implemented throughout the evaluation. All staff members participating in the Trident probe/UltraSeep demonstration are required to read this QAP, and must keep it in their possession during field activities. All demonstration participants are required to comply with the procedures identified in this QAP in order to determine that the data collected are of known and documented quality, and are useful for the purposes for which they were collected.

C2.2 QUALITY ASSURANCE RESPONSIBILITIES

A well-organized project team, combined with adequate experience and proper training, will ensure consistent quality throughout the Trident probe/UltraSeep demonstration. Section 8 provides points of contact and project roles, while the organization of demonstration team members is shown in Figure C2-1. Primary responsibility for execution of the demonstration will be taken by Bart Chadwick, SPAWAR Systems Center San Diego (SSC San Diego), and Amy Hawkins, Naval Facilities Engineering Service Center (NFESC). The primary site representatives are Mike Singletary and Barbara Nwokike (EFD South). Primary responsibility for regulatory technical review will be with Bruce Labelle, California Environmental Protection Agency (Cal/EPA). QA officer for the project will be Joel Guerrero (SSC San Diego), who will coordinate all QA activities with site and laboratory personnel.

C2.3 DATA QUALITY PARAMETERS

C2.3.1 Project Description

The overall objective of this project is to field demonstrate and evaluate the effectiveness of two technologies for characterizing coastal contaminant migration. The technologies include recently commercialized versions of a screening probe for determining where groundwater may be discharging, and an integrated seepage meter and water sampling system for quantifying discharge rates and chemical loading:

The Trident p is a combined conductivity sensor, porewater sampler, and temperature sensor system that utilizes salinity, temperature, and chemical contrasts between groundwater and surface water to map areas of potential groundwater discharge. UltraSeep is an integrated ultrasonic seepage meter and water sampling system for quantifying discharge rates and chemical loading from groundwater flow to coastal waters.

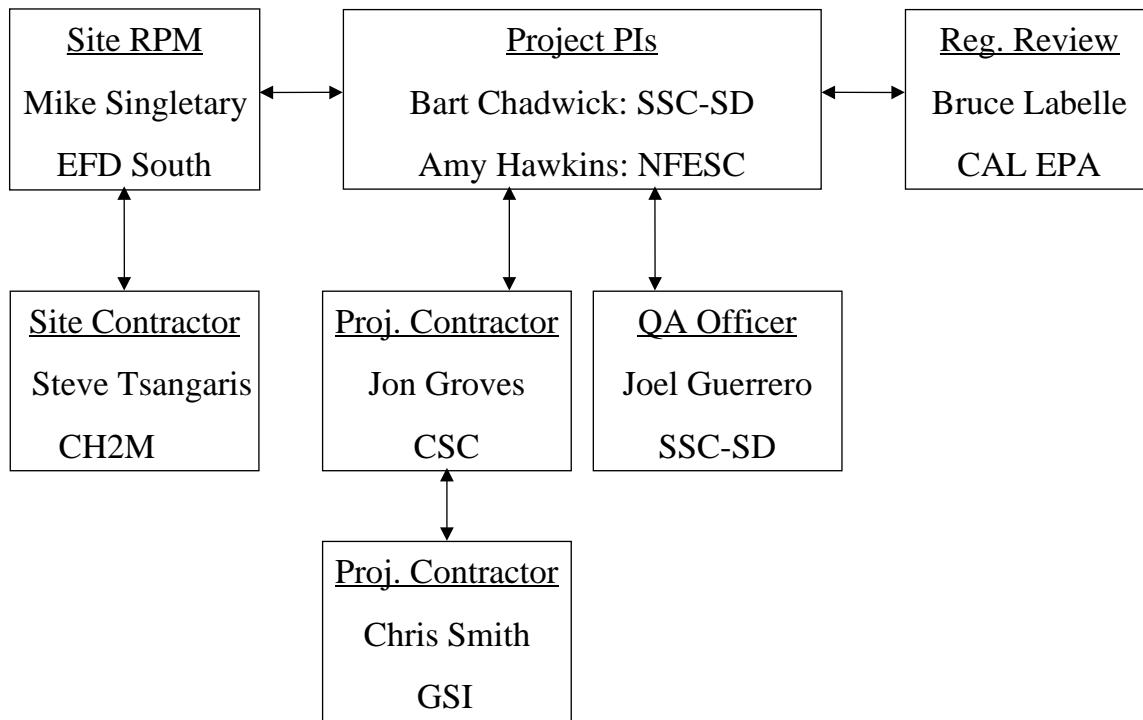


Figure C2-1. Organization of NTC Orlando demonstration team.

The purpose of this demonstration is to perform a full-scale technology evaluation in the field using the Trident probe and the UltraSeep. The technologies will be demonstrated in offshore areas adjacent to known historical landfills or hazardous waste sites where documented evidence exists of potential contaminant migration to the surface water. The demonstration will be performed at two locations: Naval Support Activity (NSA) Panama City, Panama City, Florida, and Naval Training Center (NTC) Orlando, Orlando, Florida. The primary contaminant of concern at Operable Unit 4 NTC Orlando is tetrachloroethane (PCE) and its degradation products, which have been detected at concentrations exceeding the surface water cleanup target level along the shoreline of Lake Druid (Southern Division Naval Facilities Engineering Command, 2001; Southern Division Naval Facilities Engineering Command, 2004). An extraction and treatment system has been installed; however, it is unclear whether the PCE is continuing to enter the lake and at what rate. The specific objectives of this field effort are as follows:

1. Demonstrate that the Trident probe can be used to help delineate areas where groundwater seepage is occurring..
2. Demonstrate that the UltraSeep system can be used to quantify the flow of groundwater and concentration of contaminants that may be impinging on the surface water system..
3. Demonstrate the technology to end-users to determine the utility of these tools for making decisions at DoD coastal landfills. and hazardous waste sites..
4. Quantify costs associated with the operation of each of the technologies.

Sampling objectives will be achieved based on the documented performance of the Trident probe and UltraSeep systems at the demonstration site compared to the qualitative and quantitative criteria specified in this plan (Section 4).

C2.3.2 Data Types and Uses

A number of different data types will be collected as part of the Trident probe/UltraSeep demonstration project (Tables C2-1 and C2-4). The data types are targeted for the same general purpose, which is to meet the objectives described above, but may have different specific uses with the project framework as described below.

Horizontal Trident probe mapping of conductivity and temperature contrast at the groundwater–surface water interface in Lake Druid will be used to identify likely areas of groundwater discharge to the lake. Conductivity is not expected to be helpful in this freshwater environment; however, temperature contrasts should be seen. If no areas of temperature/conductivity contrast can be identified, then it will be concluded that the point of discharge is too diffuse to be isolated.

Horizontal Trident probe mapping of VOCs at the groundwater–surface water interface in Lake Druid will be used to identify potential environmental risk relative to media protection standards and to determine the extent of natural attenuation between the shoreline wells and the point of release to the lake. If Trident probe subsurface VOC samples are below the SWCTL (PCE, 8.85 ppb; TCE, 80.7 ppb; 1,1-DCE, 3.2 ppb), then it will be concluded that the extraction and treatment system and natural processes are attenuating the VOC plume such that no risk to the environment exists. If Trident probe subsurface VOC samples exceed the SWCTL, then it will be concluded that potential risk to the environment is present, and UltraSeep water samples will be collected to determine the actual concentration and mass loading of VOCs discharging to the bay.

Continuous UltraSeep discharge measurements of groundwater to Lake Druid over a 24-hour period will be used to quantify the mean discharge rate. A positive mean discharge rate indicates that groundwater is discharging to the bay at that location.

Flow-proportional UltraSeep sampling of groundwater discharge to Lake Druid is used to determine the concentration and mass of VOCs discharging to the lake. If UltraSeep VOC discharge concentrations are below the SWCTL, then it will be concluded that natural processes are attenuating the VOC plume such that no risk to the environment exists. If UltraSeep VOC discharge concentrations exceed the SWCTL, then it will be concluded that potential risk to the environment is present and surface water concentrations will be measured to determine the extent of the risk.

Measurement of surface water concentrations of VOCs in Lake Druid will be used to determine if groundwater discharge from OU 4 is leading to detectable increases in VOC surface water concentrations. If Trident probe and UltraSeep data indicate significant VOC discharge to surface water, surface water concentrations will be used to determine the extent of potential environmental risk. If Trident probe and UltraSeep data indicate limited or no VOC discharge, surface water concentrations will be used to validate the absence of risk.

Water levels and VOC concentrations in piezometers installed at a subset of stations will be used to validate the Trident probe/UltraSeep results. Because the Trident probe/UltraSeep are new technologies, it is important to provide an independent validation of the results using a previously accepted technology. If the water levels in the piezometers indicate a positive, vertical hydraulic gradient in the piezometers would validate a measured positive discharge

rate in the UltraSeep. Presence or absence of VOCs in the groundwater sampled will serve as verification of the Trident probe/UltraSeep VOC sample results.

Table C2-1. Trident probe sensor parameters.

Parameter
Sub-surface sediment temperature
Sub-surface sediment conductivity
Surface water temperature
Surface water conductivity

Table C2-2. Trident probe water quality sample parameters.

Parameter
Sub-surface groundwater temperature
Sub-surface groundwater conductivity
Surface water temperature
Surface water conductivity

Table C2-3. UltraSeep sensor parameters

Parameter
Discharge flow rate
Funnel water temperature
Funnel water conductivity

Table C2-4. Trident probe sub-surface and surface water and UltraSeep discharge sample VOC analytes, method detection limits, and reporting limits.

	MDLs for EPA 8260B	Instrument IDs: VOA-1B & VOA-2	Matrix: Water
		Reporting Limit	MDL
	Compound Name	(ppb)	(ppb)
1	1,1,1,2-Tetrachloroethane	1	0.16
2	1,1,1-Trichloroethane	1	0.15
3	1,1,2,2-Tetrachloroethane	1	0.20
4	1,1,2-Trichloroethane	1	0.22
5	1,1-Dichloroethane	1	0.13
6	1,1-Dichloroethene	1	0.18
7	1,1-Dichloropropene	1	0.18
8	1,2,3-Trichlorobenzene	1	0.29
9	1,2,3-Trichloropropane	1	0.22
10	1,2,4-Trichlorobenzene	1	0.25
11	1,2,4-Trimethylbenzene	1	0.14
12	1,2-Dibromo-3-chloropropane	2	0.83
13	1,2-Dibromoethane	1	0.15
14	1,2-Dichlorobenzene	1	0.15
15	1,2-Dichloroethane	1	0.18
16	1,2-Dichloropropane	1	0.13
17	1,3,5-Trimethylbenzene	1	0.16
18	1,3-Dichlorobenzene	1	0.15
19	1,3-Dichloropropane	1	0.21
20	1,4-Dichlorobenzene	1	0.12
21	2,2-Dichloropropane	1	0.17
22	2-Butanone (MEK)	5	2.6
23	2-Chlorotoluene	1	0.14
24	2-Hexanone	2	1.4
25	4-Chlorotoluene	1	0.15
26	Acetone	5	4.08
27	Benzene	1	0.14
28	Bromobenzene	1	0.11
29	Bromochloromethane	1	0.21
30	Bromodichloromethane	1	0.19
31	Bromoform	1	0.24
32	Bromomethane	2	0.57
33	Carbon Disulfide	2	0.28
34	Carbon Tetrachloride	1	0.14
35	Chlorobenzene	1	0.10

Table C2-4. Trident probe sub-surface and surface water and UltraSeep discharge sample VOC analytes, method detection limits, and reporting limits. (continued)

	MDLs for EPA 8260B	Instrument IDs: VOA-1B & VOA-2	Matrix: Water
		Reporting Limit	MDL
	Compound Name	(ppb)	(ppb)
36	Chloroethane	1	0.3
37	Chloroform	1	0.15
38	Chloromethane	1	0.19
39	cis-1,2-Dichloroethene	1	0.22
40	cis-1,3-Dichloropropene	1	0.17
41	Dibromochloromethane	1	0.17
42	Dibromomethane	1	0.17
43	Dichlorodifluoromethane	1	0.38
44	Ethylbenzene	1	0.11
45	Hexachlorobutadiene	1	0.25
46	Isopropylbenzene	1	0.11
47	m,p-Xylenes	2	0.24
48	Methyl isobutyl ketone (MIBK)	2	1.24
49	Methyl tert-butyl ether (MTBE)	1	0.33
50	Methylene chloride (DCM)	1	0.16
51	Naphthalene	3	0.79
52	n-Butylbenzene	1	0.26
53	n-Propylbenzene	1	0.13
54	o-Xylene	1	0.15
55	p-Isopropyltoluene	1	0.13
56	sec-Butylbenzene	1	0.15
57	Styrene	1	0.15
58	tert-Butylbenzene	1	0.14
59	Tetrachloroethene	1	0.18
60	Toluene	1	0.14
61	trans-1,2-Dichloroethene	1	0.18
62	trans-1,3-Dichloropropene	1	0.21
63	Trichloroethene	1	0.17
64	Trichlorofluoromethane	1	0.12
65	Vinyl Chloride	1	0.18
66	tert-Butyl Alcohol (TBA)	5	0.99
67	Di-Isopropyl Ether (DIPE)	1	0.44
68	Ethyl tertiary butyl ether (ETBE)	1	0.58
69	Tertiary amyl methyl ether (TAME)	1	0.59

C2.3.3 Data Quality Requirements

The QA objective of this field investigation is to obtain results that are of known and acceptable quality and are representative of the conditions present at the site. The sampling plan for the Trident probe/UltraSeep demonstration has been developed to ensure the collection of sufficient samples from appropriate locations to achieve the goals described in the DQOs. Field sampling procedures will include safeguards to ensure that the samples provided to the laboratories are intact and representative of field conditions.

Measurement quality objectives (MQOs) have been established for this project to ensure that the collected data are of known and sufficiently high quality to support the project objectives. Quantitative MQOs are described in Subsections C2.3.1 through C2.3.6, and in Tables C2-5 and C2-6, including requirements for precision, accuracy, representativeness, completeness, and/or comparability (PARCC).

C2.3.3.1 Precision

Precision is the reproducibility of measurements of the same characteristic, usually under a specific set of conditions. For replicate measurements, precision is expressed as the relative percent difference (RPD), the standard deviation (SD), or the relative standard deviation (RSD). Precision for the Trident probe and UltraSeep sensors, including temperature and conductivity, will be assessed on the basis of SDs calculated from replicate analysis performed under controlled laboratory conditions. Sensor replicates will consist of a minimum of 10 individual measurements at the same station. For the Trident probe and UltraSeep VOC analysis, precision will be assessed on the basis of RPDs calculated from replicate analysis of samples collected at a subset of stations in the field (minimum of 1 out of each 10 stations).

C2.3.3.2 Accuracy

Accuracy is the degree to which a measurement agrees with the true value. For Trident probe and UltraSeep sensors, accuracy will be assessed on the basis of sensor readings in controlled laboratory conditions. Known conditions for the conductivity sensor will be achieved using National Institute of Standards and Technology (NIST)-certified standards and validated using a laboratory conductivity cell. Known conditions for temperature will be achieved using a temperature bath and validated using a highly accurate, calibrated digital oceanographic thermometer. Analytical accuracy for the Trident probe and UltraSeep VOC samples will be assessed on the basis of matrix spike matrix strike duplicate (MS/MSD) samples. MS/MSD samples or blank spike samples analyzed at a frequency of one for every 20 samples. Accuracy is expressed in terms of percent recovery.

C2.3.3.3 Representativeness

Representativeness is a qualitative expression of the degree to which sample data accurately represent the characteristics of a population, parameter variations at a sampling point, or an environmental condition that they are intended to represent. Representativeness is maximized by (1) selecting the appropriate number of samples and sampling locations, and (2) using appropriate and established sample collection, handling, and analysis techniques to provide information that reflects actual site conditions.

C2.3.3.4 Completeness

Completeness assesses the amount of valid data obtained from a measurement system. The percent completeness is calculated by the number of samples yielding acceptable data divided by the total number of samples planned to be collected and multiplied by 100. The data validation process will determine whether a particular data point is valid and acceptable, estimated and acceptable, or rejected and unacceptable. Complete results are considered acceptable and usable when they are valid or estimated. Sampling results that are considered rejected and unacceptable are considered incomplete. For the Trident probe sensors, the objective for the degree of completeness is 90 percent of those stations where direct-push operations are feasible. For the UltraSeep sensors, the objective for the degree of completeness is 90 percent of the operating duration of the deployment. For the Trident probe and UltraSeep VOC samples, the objective for the degree of completeness is 95 percent of the samples that are successfully obtained using the systems.

C2.3.3.5 Comparability

Comparability is a qualitative parameter that expresses the degree of confidence that one data set may be compared to another. This goal is achieved through the use of (1) standardized techniques to collect and analyze samples, and (2) appropriate units to report analytical results. The comparability of the data will be maximized by using standard analytical methods when possible, reporting data in consistent units, reporting data in tabular format, and validating the results against commonly accepted methodologies.

Table C2-5. Measurement quality objectives for Trident probe and UltraSeep sensors.

Parameter	Range	Accuracy	Precision
Trident probe Temperature	-5 to +45 °C	±0.1 °C	0.05 °C
Trident probe Conductivity	0 to 80 mS/cm	±2% FS	2 mS/cm
UltraSeep flow	0 to 50 cm/d	1 cm/d	0.5 cm/d
UltraSeep Temperature	-5 to +45 °C	±0.1 °C	0.05 °C
UltraSeep Conductivity	0 to 80 mS/cm	±2% FS	2 mS/cm

Table C2-6. Measurement quality objectives for VOC analysis.

Chemical Analysis	Method Reference	Units	Method Reporting Limit	Bias (%)	Precision (RPD)	Completeness (%)
VOCs	EPA 8260B	g/L	1 to 5	70 to 130	±30	95

C2.3.3.6 Documents and Records

Procedures, observations, and test results will be documented for all sample collection, laboratory analysis and reporting, and data validation activities. In addition to data reports provided by the laboratories, reports will be prepared that address data quality and usability, provide tabulated laboratory and field data, and interpret the Trident probe/UltraSeep data.

C2.3.3.6.1 Field Records

Field records will be maintained during all stages of sample collection and preparation for shipment to the laboratory. Field records will include the following:

- Field logbook to record daily sampling activities, conditions, and locations
- Sample labels
- Combined chain-of-custody/sample analysis request (CoC/SAR) forms
- Custody seals to monitor collar security during shipment
- Photographic equipment

C2.3.3.6.2 Laboratory Data Reports

The laboratory will perform data reduction as described in each test method for this project, and submit a complete data package with full documentation for all analyses. The laboratory quality assurance officer is responsible for reviewing laboratory data packages and checking data reduction prior to submittal. The laboratory will provide all information required for a complete quality assurance review including the following:

- A cover letter describing analytical procedures and methods that were followed and any problems that were encountered during the analyses
- A summary of analyte concentrations and method reporting limits
- Laboratory data qualifier codes appended to analyte concentrations and a summary of code definitions
- Initial and continuing calibration data, including instrument printouts and quantification summaries for all analytes
- Results for method and calibration blanks
- Results for all QA/QC checks, including laboratory control samples, matrix spike samples, surrogate spikes, duplicate matrix spike samples, and laboratory duplicate or triplicate samples
- Original data quantification reports for all analyses and samples

C2.3.3.6.3 Data Quality and Usability

A data quality and usability analysis will be performed with the Trident probe/UltraSeep demonstration. The analysis will summarize the results of the data validation and data quality review, and will describe any significant quality assurance problems that were encountered. All data and any qualifiers applied to the data as a result of the quality assurance review will be included in the final report.

C2.4 DEMONSTRATION PROCEDURES

C2.4.1 Sampling Design

The sampling program is divided into two phases. In phase 1, the Trident probe will be used to map the horizontal distribution of temperature contrast, conductivity contrast, sub-surface VOCs, and surface water VOCs. Based on the results from the Trident probe survey, stations will be selected for UltraSeep deployment. The UltraSeep will then be used to quantify the discharge rate of groundwater to surface water, and the concentration of VOCs in the

discharge water. Both phases will include parallel sampling with piezometers as a method of comparative validation of the new Trident probe/UltraSeep technologies.

Validation sampling using piezometers will occur along the five central transect stations (T3), and at the three UltraSeep/surface waters sampling stations. For the Trident probe validation, piezometers will be installed to 2 ft below the sediment surface. The 2-ft piezometer will be used to collect water samples for validation of the Trident probe results. Water samples from the 2-ft piezometer will be collected at the same time the corresponding Trident probe water sample is collected.

For the UltraSeep validation, piezometers will be installed 1 and 3 ft below the sediment surface. The 1-ft piezometers will be used to evaluate the near-surface VOC concentrations that would be discharging to the bay for comparison to UltraSeep discharge samples. Water levels from the 3-ft piezometers will be recorded on a periodic basis throughout the tidal cycle to determine the vertical hydraulic gradient as a means of validating UltraSeep direct flow measurements.

C2.4.2 Sampling Methods

C2.4.2.1 Trident Probe Sub-Surface And Surface Water Sampling

Trident probe stations will be sampled for temperature/conductivity contrast and sub-surface and surface VOC water sampling. Trident probe sampling locations are located along five offshore transects extending eastward from the shoreline with five stations each. Along shore and offshore, sample spacing is approximately 50 ft. Trident probe sub-surface temperature/conductivity and VOC sampling will be performed at approximately 2 ft below the sediment surface, depending on the practical penetration depth of the probe. Surface water will be collected from the water column approximately 1 ft above the sediment surface.

Trident probe sampling will be timed to occur during daylight hours, when sampling conditions are most favorable, and safety conditions are optimal. Trident probe sampling procedures are described in detail in the system documentation and operating manuals (Chadwick et al., 2003b; Appendix A). Sample preservation and holding time requirements are shown in Table C2-7.

Table C2-7. Sample preservation and holding time requirements.

Analyte	Sample Size	Container	Preservation and Handling	Maximum Holding Time
VOCs	2 x 40 ml	40-ml VOC vial with Teflon®-lined septum.	1:1 HCl to pH<2; Cool to 4 ±2 °C	14 days

At each station, the following general procedure will be used:

- Occupy the sampling station using the Trident probe Global Positioning System (GPS) unit or using a previously deployed marker buoy
- Secure the sampling platform using lines or anchors as necessary to minimize movement during the sampling operation
- Lower the probe tips to within 1 ft of the sediment surface and hold while temperature and conductivity readings stabilize
- Record position, temperature, and conductivity readings to the Trident probe laptop

- Collect the surface water sample using the water sampler on the Trident probe (see details below)
- Push the Trident probe into the sediment to the 2-ft measurement depth (set stopper plate accordingly) and hold while temperature and conductivity readings stabilize
- Record position, temperature, and conductivity readings to the Trident probe laptop
- Collect the sub-surface groundwater sample using the Trident probe water sampler (see details below)
- Decontaminate the Trident probe water sampler and the ancillary water sampling equipment
- If the station is a validation station, purge the piezometer and collect the sub-surface groundwater sample using the piezometer (see validation sampling details below)
- Decontaminate the ancillary water sampling equipment
- Move to the next station and repeat the operation

Surface water samples for VOC analysis will be collected using the Trident probe water sampling probe connected by 1/16-inch inside diameter Teflon® tubing to an in-line VOA bottle filler (Solinst, Inc.) powered by a low-flow peristaltic pumping system, or alternatively by direct collection using a pre-cleaned 100-ml glass syringe. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) will be pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994.

For the Trident probe method, the probe is held at a depth of 1 ft above the sediment surface using the push-pole system. A Y-valve is used to direct the sample water to a purging syringe first, and then to the sampling system. The purging syringe is used to withdraw approximately 60-ml (an estimated three sampler volumes, assuming a 10-m sample tube), and the sample system is then used to fill two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential, and total dissolved solids).

For the syringe method, the syringe is held at a depth of 1 ft above the sediment surface by a wader or diver, being careful not to disturb the sediment surface. The 100-ml syringe volume is drawn, and the sample is then transferred to two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential, and total dissolved solids). The VOA bottles are pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw-cap vials with PTFE-faced silicone septa.

Groundwater for VOC analysis will be collected using the water sampling probe on the Trident probe connected by 1/16-inch inside diameter Teflon® tubing to an in-line VOA bottle filler (Solinst, Inc.) powered by a low-flow peristaltic pumping system. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) will be pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA, 1996.

The probe is inserted 2 ft below the sediment surface using the push-pole system. A Y-valve is used to direct the sample water to a purging syringe first, and then to the sampling system. The purging syringe is used to withdraw approximately 60-ml (an estimated three sampler volumes, assuming a 10-m sample tube), and the sample system is then used to fill two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter (Myron L, Co.) water quality analyzer (temperature, conductivity,

pH, oxidation-reduction potential, and total dissolved solids). The VOA bottles are pre-cleaned, amber glass, 40 ml, pre-acidified (pH 2), screw cap vials with PTFE-faced silicone septa.

C2.4.2.2 UltraSeep Sampling

A minimum of three UltraSeep stations will be sampled for specific discharge, VOC discharge, and temperature/conductivity of the discharge. After consultation with the site manager, UltraSeep sampling locations will be selected based on the Trident probe survey results. The locations will be selected to target areas of highest potential water and VOC discharge.

UltraSeep measurements will extend over a complete diurnal tidal cycle. UltraSeep water samples will be collected approximately every 2.5 hours, depending on discharge conditions. Sampling procedures for the UltraSeep are described in detail in the system documentation and operating manuals (Chadwick et al., 2003b; Appendix A). Sample preservation and holding time requirements are shown in Table C2-7. The following general procedure will be used at each station:

- Occupy the sampling station using the a GPS unit or using a previously deployed marker buoy
- Deploy the UltraSeep by diving or wading, depending on water depth
- Assure that the funnel knife edge is completely sealed into the sediment
- Assure that any air that may have been trapped in the funnel or the flow tube has been purged
- Zero the flow meter
- Start the UltraSeep system, allowing a 1-2 hour period prior to the collection of any discharge samples to allow the system to equilibrate following any flow disturbance that may have been caused by the deployment process
- Allow the sensor system and water sampler to run for the full tidal cycle (see water sampling details below)
- Regularly check the flow meter readings and bag filling to assure that the system is functioning properly
- Collect validation samples from the 1 ft piezometers during periods when discharge is noted from the flow meter (see validation sampling details below)
- Retrieve the system and return to the shore facility
- Decontaminate the system
- Redeploy to the next station and repeat the procedure

Discharge water samples for VOC analysis will be collected using the water sampling system on the UltraSeep. The system draws samples from the seepage funnel to the Teflon® sampling bags via a 1/16-inch inside diameter Teflon® tube using the built-in peristaltic pump. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) will be pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994.

The UltraSeep is deployed on the bottom, and up to 10 water samples are collected at an interval of about 2.4 hours in proportion to the measured discharge rate. The entire deployment period is about 24 hours. Following retrieval of the UltraSeep, the water samples are

transferred from the sampling bags to two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential, and total dissolved solids). The VOA bottles are pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw-cap vials with PTFE-faced silicone septa.

C2.4.2.3 Validation Sampling

Validation sampling using piezometers will occur along the six central transect stations (T3), and at the three UltraSeep/surface waters sampling stations. For the Trident probe validation, piezometers will be installed 2 ft below the sediment surface. The 2-ft piezometer will be used to collect water samples for validation of the Trident probe results. Water samples from the 2-ft piezometer will be collected at the same time the corresponding Trident probe water sample is collected.

For the UltraSeep validation, piezometers will be installed 1 and 3 ft below the sediment surface. The 1-ft piezometers will be used to evaluate the near-surface VOC concentrations that would be discharging to the bay for comparison to discharge samples collected by the UltraSeep. Water levels from the 3-ft piezometers will be recorded on a periodic basis throughout the tidal cycle to determine the vertical hydraulic gradient as a means of validating UltraSeep direct flow measurements.

C2.4.2.4 Sub-Surface Groundwater Validation Water Samples

Validation groundwater samples for VOC analysis will be collected using stainless-steel drive-point piezometers ½-inch inside diameter Teflon® tubing to an in-line VOA bottle filler (Solinst, Inc.) powered by a low-flow peristaltic pumping system. Prior to sampling, all sampling components (except pre-cleaned VOA bottles) will be pre-cleaned in accordance with the procedure described in Section 3.6.1 and U.S. EPA 1994.

The piezometer is driven to a depth of 2 ft (Trident probe validation) or 1 ft (UltraSeep validation) below the sediment surface using a slide hammer or rotary hammer system. The piezometer is developed using the low-flow pump and the piezometer is allowed to re-equilibrate with the groundwater. The sample system is then used to fill two 40-ml VOA bottles (no head space) and a third 40-ml bottle for water quality analysis using the UltraMeter water quality analyzer (temperature, conductivity, pH, oxidation-reduction potential [ORP], and total dissolved solids [TDS]). The VOA bottles are pre-cleaned, amber glass, 40-ml, pre-acidified (pH 2), screw-cap vials with PTFE-faced silicone septa.

C2.5 SAMPLE HANDLING AND CUSTODY

Documentation during sampling activities is essential to ensure proper sample identification, integrity, and custody. A description of standard sample custody procedures that will be used to maintain and document sample integrity during collection, transportation, storage, and analysis is provided in Subsections C2.5.1 through C2.5.5.

C2.5.1 Sample Custody Procedures

The field team will follow standard EPA chain-of-custody procedures for each sample as it is collected. Until shipped to the laboratory, the samples will be retained at all times in the field crew's custody.

A sample is considered in custody if one of the following statements applies:

- It is in a person's physical possession or view
- It is in a secure area with restricted access
- It is placed in a container and secured with an official seal so that the sample cannot be reached without breaking the seal

The quality assurance officer is responsible for ensuring proper sample handling and documentation that will allow tracking the possession and handling of individual samples from the time of collection to laboratory receipt. The laboratory QC manager is responsible for establishing a sample control system that will allow tracking sample possession from laboratory receipt to final disposition of the sample.

C2.5.2 Sample Labels

A sample label will be affixed to all sample containers sent to the laboratory. This identification label will be completed with the following information written in indelible ink:

- Project name and location
- Sample location
- Sample identification number
- Date and time of sample collection
- Preservative used
- Sample collector's name and initials
- Filtering (if applicable)
- Type of sample (grab or composite)
- Analysis required

If a sample is split with another party, sample labels with identical information will be attached to each sample container. After labeling, each sample will be refrigerated or placed in a cooler containing ice or "blue ice" to maintain the sample temperature at $4 \pm 2^{\circ}\text{C}$.

C2.5.3 Sample Documentation

Sampling activities during the field effort require several forms of documentation. The documents are prepared to maintain sample identification and chain of custody, and provide records of significant events or observations. In addition, other documents will be prepared, such as field logbooks.

C2.5.4 Shipping Procedures

All U.S. Department of Transportation regulations will be followed during sample packaging and shipment. Samples will be collected at the end of each field study phase. They will be transferred to appropriate laboratory containers, labeled, placed in a chilled ice chest, and shipped overnight to the laboratory.

C2.5.5 Laboratory Procedures

Upon receipt of a cooler, laboratory personnel will review the contents, and sign and retain the chain-of-custody record and the air bill.

Information that will be recorded on the chain-of-custody record or another appropriate document at the time of sample receipt will include the following:

- Status of the custody seals
- Temperature of the cooler upon receipt
- Identification number of any broken sample containers
- Description of discrepancies between the chain-of-custody records, sample labels, and requested analyses
- Storage location of the sample and sample extracts

Laboratory personnel will contact the analytical coordinator regarding discrepancies in paperwork and sample preservation, and will document nonconformance and corrective actions in accordance with laboratory standard operating procedures (SOPs). These procedures will be available on file at the laboratory. After samples have been accepted, checked, and logged in by the laboratory, they must be maintained in a manner consistent with the custody and security requirements specified in the laboratory QA plan.

All samples and sample extracts will be assigned to a specific refrigerator within the laboratory. All laboratory refrigerators will be assigned a number, and the refrigerator number will be recorded on an appropriate document that references the sample and extract locations. Only laboratory personnel will have access to the samples and will be required to sign a log sheet when removing samples and extracts from the refrigerators or replacing them. These log sheets will provide a chain-of-custody record as the samples move within the laboratory. A chain-of-custody record, similar to the chain-of-custody record used for sampling procedures, will be completed for samples removed from the laboratory for disposal or other purposes.

C2.6 ANALYTICAL METHODS

C2.6.1 VOCs

VOC samples from the Trident probe, UltraSeep, surface water, and validation surveys will all be analyzed following EPA method 8260B at a remote laboratory or using an on-site mobile laboratory (Appendix B). Details of the method, analytical instrumentation, matrix considerations, concentration units, statistical procedures and detection limits are all described in U.S. EPA (1996).

C2.6.2 Water Quality

Sub-samples of the Trident probe, UltraSeep, surface water, and validation samples will be analyzed on-site using a Myron model 6b water quality analyzer. The analyzer detects temperature, conductivity, pH, oxidation reduction potential (ORP), and total dissolved solids (TDS). The cell volumes for the measurement are 1.2 ml (pH/ORP) and 5 ml (temperature /conductivity/TDS). Quoted accuracy and precision levels for the meter are shown in Table C2-8. The meter is calibrated to certified NIST standards prior to each survey.

Table C2-8. UltraMeter water quality analyzer Specifications.

	Range	Resolution	Accuracy
pH	0 to 14 pH	0.01 pH	0.01 pH
ORP	± 999 mV	± 1 mV	± 1 mV
Conductivity	0 to 9999 μ S	0.01 < 100 μ S	± 1% of reading
	10 to 200 μ S	0.1 < 1000 μ S	
	5 autoranges	1.0 > 1000 μ S	
TDS	0 to 9999 ppm	0.01 < 100 ppm	± 1% of reading
	10 to 200 ppt	0.1 < 1000 ppm	
	5 autoranges	1.0 > 1000 ppm	
Resistivity	10 K Ω to 30 M Ω	0.01 < 100 K Ω	± 1% of reading
		0.1 < 1000 K Ω	
		0.01 > 1 M Ω	
Temperature	32 to 160F	0.1F	± 0.1F

C2.7 QUALITY CONTROL REQUIREMENTS

Quality control requirements consist of field quality control checks and laboratory quality control checks. Field quality control checks are intended to verify that contamination during field sampling did not occur and the Trident probe and UltraSeep are functioning properly. Laboratory quality control checks are intended to verify that samples were analyzed to an acceptable level of PARCC parameters.

C2.7.1 Field Quality Control Checks

Field quality control checks include equipment rinsate blanks, field duplicates, and trip blanks, which are described in Subsections C2.7.1.1 thorough C2.7.1.3.

C2.7.1.1 Equipment Rinsate Blanks

Equipment rinsate blanks will be collected for the Trident probe, UltraSeep, and the piezometers used to identify possible contamination associated with the sampling environment or the sampling equipment. These blanks will be collected for the Trident probe by drawing a water sample through the probe from a container of deionized water using the same sampling equipment as is used during normal system operations.

For the UltraSeep, equipment blanks will be collected by (1) pouring deionized water over the funnel into a jar, and (2) pumping water through the UltraSeep onboard sampling system into a Teflon® sampling bag and collecting the blank from the bag.

For the piezometers, rinsate blanks will be collected by placing the piezometer tip into a container of deionized water and drawing a water sample through the piezometer using the same sampling equipment that is used during normal system operations.

C2.7.1.2 Field Duplicates

Field duplicates will be collected to assess the homogeneity of the samples collected in the field and the overall precision of the sampling process. Field duplicates are automatically collected at every station for the Trident probe and piezometers using the VOA bottle filler.

C2.7.1.3 Trip Blanks

One trip blank for each sample shipment will be collected by placing a sample of deionized water in a sample cooler at the beginning of the demonstration. The trip blank will be used as a quality control measure to ensure that samples are not contaminated during sample storage and shipment to the laboratory.

C2.7.2 Laboratory Quality Control Checks

Each analytical protocol used in this technology demonstration includes specific instructions for analyzing quality control samples and completing quality control procedures during sample analysis. Laboratory QC checks are designed to assess the precision and accuracy of the analysis, demonstrate the absence of interferences and contamination from glassware and reagents, and ensure the comparability of data. Laboratory QC checks consist of method blanks, laboratory control samples, laboratory duplicates, MS/MSDs, and surrogates spike compounds, which are described in Subsections C2.7.2.1 through C2.7.2.5.

C2.7.2.1 Method Blanks

Method blanks verify that preparation of samples was contamination-free. Each batch of extracted and digested samples is accompanied by a blank that is analyzed in parallel with the rest of the samples, and carried through the entire preparation and analysis procedure. Method blanks for VOCs will be analyzed for every sample preparation group or 1 for every 20 samples, whichever is more frequent.

C2.7.2.2 Laboratory Control Samples

Laboratory control samples (LCS), reference material or spiked blanks, are used to check overall method performance. An LCS for VOCs will be analyzed for every sample delivery group or 1 for every 20 samples, whichever is more frequent.

C2.7.2.3 Replicate Laboratory Analyses

Replicate laboratory analyses are indicators of laboratory precision. Laboratory duplicates are analyzed during water sample analysis for VOCs by splitting 1 in 20 field samples or 1 sample from every sample delivery group, whichever is more frequent.

C2.7.2.4 MS/MSDs

MS/MSDs are used to assess the effects of the sample matrix on the accuracy and precision of analytical measurements. MS/MSDs for VOCs will be analyzed for every sample delivery group or 1 for every 20 samples, whichever is more frequent.

C2.7.2.5 Surrogate Spike Compounds

Surrogate spike compounds will be added to all field and QC samples for VOC analysis to evaluate the analyte recovery for each sample.

C2.7.3 Instrument and Equipment Maintenance and Calibration Requirements

Subsections C2.7.3.1 through C2.7.3.2 discuss regularly scheduled preventive maintenance and calibration procedures to keep all field and laboratory equipment in good working condition. Generally, the Principal Investigator (PI) will be responsible for ensuring that routine preventative maintenance and calibrations are performed and documented for all field instrumentation and equipment. The laboratory quality assurance officer will be responsible for ensuring that routine maintenance and calibrations are performed and documented for analytical instrumentation.

C2.7.3.1 Field Equipment

Detailed information regarding maintenance and servicing of field equipment is available in the guidance documents and manuals for the specific instrument to be used (Chadwick et al., 2003b; Appendix A). Field personnel will record service and maintenance information in field logs. General guidelines for the maintenance and calibration of the Trident probe and UltraSeep are described in Chadwick et al. (2003b).

The temperature sensors are robust and require little maintenance. The sensor area should be kept clean and free of residues. The sensor should be tested and the calibration checked prior to the demonstration to ensure that the precision and accuracy are within the manufacturer's specification. If the temperature sensor is out of specification, it can be returned to the manufacturer for recalibration, or recalibrated in the laboratory under closely controlled conditions.

The Trident probe and UltraSeep conductivity sensors are also very robust, but may require more frequent calibration. The sensor area should be kept clean and free of residues. The sensor should be tested and the calibration checked at the beginning and end of each day of operations. The calibration can be tested by immersing the sensor in a beaker filled with NIST-certified conductivity standard and comparing the measured value and replicate standard deviation with the manufacturer's specification. If the conductivity sensor is out of specification, it can be calibrated in the laboratory, or in the field using NIST-certified standards.

The Trident probe water-sampling probe should be visually inspected before and after each sub-surface push. If the filter screen is damaged, the screen should be replaced. A supply of replacement screens should be available during any field deployment that utilizes the water sampler. The sample tubing should also be inspected for kinking or damage, and repaired or replaced if necessary. The peristaltic pump tubing should also be inspected periodically to ensure that it is not damaged.

The UltraSeep flow sensor should be tested, zeroed, and calibrated prior to each demonstration. In addition, the sensor should be re-zeroed following deployment at each station. Calibration of the flow sensor is generally carried out in the laboratory under controlled conditions.

C2.7.3.2 Laboratory Equipment

The analytical laboratory will prepare and follow a maintenance schedule for each instrument used to analyze demonstration samples. All instruments will be serviced at scheduled intervals to optimize factory specifications. Routine preventive maintenance and major repairs will be documented in a maintenance logbook.

Initial and continuing calibration procedures for laboratory equipment and instrumentation will be completed in accordance with the cited analytical method for each analysis. The method descriptions for each analysis specify the acceptance criteria for initial and continuing calibration and state the conditions where recalibration is necessary.

C2.7.4 Data Management

Computerized systems will be used to record, store, sort, and analyze the technical data that will be generated from the Trident probe/UltraSeep demonstration. Automated data handling processes will be used that increase data integrity by reducing errors, omissions, and ambiguities that can be introduced by manual procedures. In addition, automated procedures will be used by the analytical laboratory to capture and summarize analytical results. This will also improve efficiency and reduce errors by allowing direct electronic transfer from the laboratory to the project computer systems.

Sensor data from the Trident probe and UltraSeep can also be transferred electronically into the project data system. Information from field-log books, claims of custody/sample analysis request (COC/SAR) forms, and other sources will be entered manually into the data system. Each data record will include a unique sample code, station ID, sample type, analyte, analyte concentration, and concentration units. Data qualifiers are entered into the data system once the data validation process is completed.

Project data tables and reports are generated using standardized templates and customized retrievals and filters based on user-specified criteria. Standard templates are available for analysis of the Trident probe and UltraSeep data products. Results from the Trident probe survey are generally transformed into spatial maps using a Geographic Information System, while the UltraSeep results are generally processed as time-series output. Additional details and examples of the data analysis process are described in Chadwick et al. (2003b).

C2.8 PERFORMANCE AND SYSTEM AUDITS

This section describes the types of audits that may be conducted, appropriate corrective action procedures that will be taken if problems occur in the field and the laboratory, and QA reports to management. QA audits evaluate the capability and performance of a measurement system or its components, and identify problems that warrant correction.

Audits may include reviews of project plan adherence, training status, health and safety procedures, activity performance and records, budget status, QC data, calibrations, conformance to SOPs, and compliance with laws, regulations, policies, and procedures. Personnel who are independent of the sampling and analytical teams conduct internal audits. These may be ESTCP or Cal/EPA certification program auditors. Copies of field audit reports will be forwarded to the Trident probe/UltraSeep PI. Subsections C2.8.1 through C2.8.4 describe laboratory system, performance, and field audits, and corrective action procedures,

C2.8.1 System Audits

System audits include a thorough evaluation of field and laboratory QC procedures, and are normally completed before data are collected. This type of audit may consist of site reviews of measurement systems, including facilities, equipment, and personnel. In addition, measurement, QC, and documentation procedures may be evaluated. System audits are conducted on a regularly scheduled basis; the first audit is conducted shortly after a system becomes operational.

C2.8.2 Performance Audits

A performance audit reviews the existing project and QC data to determine the accuracy of a total measurement system or a system component. Performance audits of sampling and analysis procedures will be conducted for field and laboratory activities. The audits may consist of the following, as appropriate:

- Field audit during the demonstration to verify that sampling and monitoring procedures and frequencies specified in the technology evaluation plan are followed
- Laboratory audit during analysis of evaluation samples to verify that procedures and frequencies specified in the technology evaluation plan are followed
- Issuance of blind QC samples for analysis of specified critical parameters
- Internal audit routines for the laboratory are described in the laboratory QA plan

C2.8.3 Field Audits

A field audit involves a site visit by the auditor or auditing team. Items to be examined include the following:

- Availability and implementation of SOPs
- Calibration and operation of equipment
- Packaging, storage, and shipping of samples
- Documentation of on-site procedures and instructions
- Documentation of non-conformances

C2.8.4 Corrective Action Procedures

An effective QA program requires prompt and thorough correction of non-conformance conditions affecting quality. Rapid and effective corrective action minimizes the possibility that questionable data or documentation will be produced.

Two types of corrective actions exist: immediate and long term. Immediate corrective actions include correction of documentation deficiencies or errors, repair of inaccurate instrumentation, or correction of inadequate procedures. Often, the source of the problem is obvious and can be corrected when first observed. Long-term corrective actions are designed to eliminate problem sources. Examples of long-term corrective actions are correction of systematic errors in sampling or analysis, and correction of procedures producing questionable results. Corrections can be made through additional personnel training, instrument replacement, or procedural improvements. One or more corrections may be necessary.

All QA problems and corrective actions will be documented to provide a complete record of QA activities and to help identify needed long-term corrective actions. Defined responsibilities are required for scheduling, performing, documenting, and ensuring the effectiveness of the corrective action. Subsections C2.8.4.1 and C2.8.4.2 describe the corrective action procedures to be followed in the field and laboratory.

C2.8.4.1 Field Procedures

Field non-conformance conditions are defined as occurrences or measurements that are unexpected or that do not meet established acceptance criteria and will affect data quality if corrective action is not implemented.

Examples of non-conformances include the following:

- Incorrect use of field equipment
- Improper sample collection, preservation, and shipment procedures
- Incomplete field documentation, including CoC records
- Incorrect decontamination procedures
- Incorrect collection of QC samples

Corrective action procedures will depend on the severity of the non-conformance. In cases where immediate and complete corrective action is implemented by field personnel, the corrective actions will be recorded in the field-log.

Non-conformances identified during an audit that have a substantial impact on data quality require that a corrective action request form be completed. This form may be filled out by an auditor or any individual who suspects that any aspect of data integrity is being affected by a field nonconformance. Each form is limited to a single non-conformance; if additional problems are identified, multiple forms will be used for documentation.

If a corrective action is required due to improper field technique, the program manager will be notified. The program manager, program scientist, and the project QA/QC officer will meet to discuss the appropriate steps to resolve the problem, and will use the following list:

- Determine when and how the problem developed
- Assign responsibility for problem investigation and documentation
- Determine the corrective action to eliminate the problem
- Set a schedule for completion of the corrective action
- Assign responsibility for implementing the corrective action
- Document and verify that the corrective action has eliminated the problem
- Include report of the problem and the corrective action taken in final report

A corrective action status report must be used by the project QA/QC officer to monitor the status of all corrective actions. In addition to a brief description of the problem and the individual who identified it, the report will list personnel responsible for determining and implementing the corrective action. The report also will list completion dates for each phase of the corrective action procedure and the due date for the project QA/QC officer to review and check the effectiveness of the solution. Follow-up data also will be listed to check that the problem has not reappeared. The follow-up review is conducted to ensure that the solution has adequately and permanently corrected the problem.

The project QA/QC officer can require that data acquisition be limited or discontinued until the corrective action is complete and the non-conformance is eliminated. The project QA/QC officer can also request re-analysis of any or all data acquired since the system was last in control.

C2.8.4.2 Laboratory Procedures

Internal laboratory corrective action procedures and a description of out-of-control situations requiring corrective action are contained in the laboratory QA plan. At a minimum, corrective action will be implemented when any of the following three conditions occur: control chart warning or control limits are exceeded, method QC requirements are not met,

or sample holding times are exceeded. Out-of-control situations will be reported to the program manager within 2 working days of identification. In addition, a corrective action report, signed by the laboratory director or project managers and laboratory QC coordinator, will be provided to the program manager.

C2.9. DATA REVIEW, VALIDATION, AND VERIFICATION

Correct equations and procedures must be used to ensure that all laboratory data generated and processed are scientifically valid, defensible, and comparable. The following subsections describe the data review, validation, verification, and reporting procedures that will be used in this evaluation.

C2.9.1 Data Review

Each analytical method contains detailed instructions and equations for calculating compound concentrations or parameters. Data will be reduced using the procedures given in the analytical methods. Final data presentation will be checked for compliance with data documentation requirements, and will be approved and certified by the laboratory senior officer. In general, data package requirements include but are not limited to the following categories:

- Custody of sample
- Performance of instruments
- Identification and quantitation of parameters
- Integrity, precision, and accuracy (QC checks) of samples

Field data recorded during sampling will be reduced to tables for review and verification. After they have been verified, the data will be compiled and reported in summary tables and figures, as appropriate. Corresponding descriptions and units of measure will also be provided to accurately reflect field conditions.

The analysts responsible for the measurements will enter raw data into logs or on data sheets. In accordance with standard document control procedures, the laboratory will maintain on file the original copies of all data sheets and logs containing raw data, signed and dated by the responsible analyst. Separate instrument logs will also be maintained by the laboratory to enable run sequences to be reconstructed for individual instruments.

C2.9.2 Data Validation and Verification

Data validation is a systematic process of reviewing and qualifying data against a set of criteria to determine that the data are adequate for their intended use. During the validation process, all results will be identified as (1) acceptable for use, (2) estimated and acceptable for limited use, or (3) rejected and unacceptable for use. Results considered rejected will be retained in the database but will not be used in quantitative evaluations. Estimated and rejected data can result from improper sampling or analytical methodology, matrix interferences, errors in data transcription, and changes in instrument performance. Erroneous results found during data validation will be identified and corrected.

C2.9.2.1 Field Validation and Verification

Field personnel will review field data to identify inconsistencies or anomalous values in accordance with the MQOs for the field equipment and instrumentation. Any inconsistencies discovered will be resolved immediately, if possible, by seeking clarification from the

personnel responsible for collecting data. All field personnel will be responsible for following the sampling and documentation procedures described in the demonstration plan and the QAP in order to assure that defensible and justifiable data are obtained. Specific requirements for field sampling include but are not limited to the following:

- Sampling locations must be fully documented and correct. Errors in sampling location (e.g., as a result of GPS failure) may result in the rejection of data for the subject station
- Sample collection procedures must be completed as planned and fully documented. Deviations from designated procedures may affect the representativeness of the samples and must be minimized and documented where they occur
- Sample shipping and handling procedures must be completed as described in the demonstration plan and the QAP, in particular, the maintenance of sample integrity and proper temperature
- Results of the field sensor tests and field quality control samples should meet MQO limits
- Failure to meet these requirements may result in the qualification or rejection of data during the data validation process

C2.9.2.2 Laboratory Validation and Verification

During analysis and reporting, laboratory personnel will assess data by reviewing raw data for any non-conformance in analytical method protocols. The laboratory QA plan describes detailed procedures for laboratory validation and corrective action. The laboratory QA plan also discusses sample control, methods of analysis, calibration procedures, document control, QC, corrective actions, QC checks, QA, and data review.

Validation will be completed on data packages for analysis of the water samples. The data reviewer is required to notify the PI of any missing information and request it from the laboratory. Data may not be eliminated from the review process. All data will continue through the validation process and be qualified and re-qualified as many times as necessary to meet the established criteria.

Full data validation will be required on approximately 10 percent of a sample data group. Data packages consist of sample results, QA/QC summaries, and a review of all raw data associated with the sample results and QA/QC summaries. Data may be qualified as estimated or rejected if any of the following quality control samples and procedures do not meet control limits:

- Sample holding times
- Method of analysis
- Initial and continuing instrument calibration
- Calibration and method blanks
- Laboratory control samples
- Matrix spike and matrix spike duplicate samples
- Surrogate recovery
- Analyte identification and quantification

Project personnel will review the data validation reports from the laboratory to (1) assess whether data quality indicators for chemical measurement were met, and (2) determine

whether the data are usable for their intended purpose. The laboratory project manager and the project QA/QC officer will approve the completed laboratory report before it is used to prepare the Trident probe/UltraSeep demonstration report.

C2.9.3 Reconciliation with Data Quality Objectives

The goal of data validation is to determine the quality of the data and to identify data that do not meet the project MQOs. Non-conforming data may be qualified as estimated or rejected as unusable. Rejected data will not be used for any purpose within the context of the demonstration except to guide recommendations for future corrective actions.

If the rejected data are needed to complete the demonstration or to make a decision at the site, it may be necessary to resample. Any decision to resample will be based on discussions among the project team. Data qualified as estimated will be used for the demonstration. These data may be less accurate or precise than unqualified data. The PI and the data users are responsible for assessing the potential ramifications of the inaccuracy or imprecision associated with the qualified data.

APPENDIX D1

HEALTH AND SAFETY PLAN—PANAMA CITY

D1.1 GENERAL DEMONSTRATION SAFETY REQUIREMENTS

Health and safety procedures during the demonstration will be in accordance with the existing Health and Safety Plan (HASP) for NSA Panama City (Naval Facilities Engineering Command, 2004). Health and safety aspects that are particular to this demonstration and are not detailed in the sections below.

D1.2 SAFETY REQUIREMENTS FOR DIVING OPERATIONS

Due to the shallow nature of the NSA Panama City demonstration site, it is anticipated that the majority of the field work can be accomplished without the need for diving operations. In the event that diving support is required, the safety procedures outlined in this section are to be adhered to, along with any applicable health and safety requirements in the HASP for the site (Naval Facilities Engineering Command, 2004).

D1.2.1 Names and Duties of Dive Team Members

Dive Supervisor: Christopher Field Smith

Divers: Chris Smith, Ron Paulsen, Jon Groves

Standby Diver: Any of the above when two are in the water

D1.2.2 Date, Time, and Locations of Dive Operations

Date: Perform diving operations on or about 17–21 August 2004

Time: 08:00 through 16:30 on 4 to 10 days.

Location: St. Andrew Bay, Panama City, Florida, adjacent to NSA Panama City.

If diving support is required, the team will be conducting diving operations for approximately 5 days. The estimated total number of dives will be between two and four per day in shallow-water conditions less than 15 ft in depth. Diving operations will be primarily to deploy seepage detection/measurement equipment in St. Andrew Bay adjacent to NSA Panama City.

D1.2.3 Diving Mode

The team will use open-circuit SCUBA diving as the diving mode for the fieldwork. The crew size will be a three-man team, all certified in cardiopulmonary resuscitation (CPR), first aid, and emergency oxygen administration, as well as certified to dive. At any time during diving operations, two members will be actively diving, and the third member will act as the safety diver.

Diving will be performed in shallow waters from 4 to 15 ft of depth within 500 ft of the shoreline adjacent to NSA Panama City. Dives will be performed from shore or from a boat. A ladder will be provided for egress of the divers when using the boat.

D1.2.4 Equipment

The team will use 80-ft³ aluminum cylinders filled with clean, dry air for the SCUBA diving air supply. The cylinders will have current hydro and visual inspections. The primary filling compressor will be located at Panama City Dive Center (4823 Thomas Drive, Panama

City Beach, Florida 32408, Tel: 850-235-3390), where the tanks will be leased. Dives will be performed with single tanks. Minimum equipment will consist of the following:

- 10 SCUBA cylinders (3000 psi, 80 cf each)
- Two AGA full face mask systems with surface support communications
- One Boat first aid kit
- One DAN O2 Emergency kit
- One time keeping/logging device for all dive profiles
- One set of matrix diving paperwork
- One log book
- One dive flag
- Three sets of diver's equipment:
 - Regulator
 - Buoyancy Compensation Device (BCD)
 - Weight belt
 - Mask
 - Snorkel
 - Fins
 - Booties
 - Gloves
 - Wetsuit or Dry suit/Protective clothing
 - Knife
 - Dive light
- Two cellular telephones with emergency numbers

D1.2.5 Oxygen Resuscitation System

A Diver Alert Network (DAN) oxygen resuscitation system capable of providing oxygen for 30 minutes will be provided. All dive team members are currently qualified to operate this system

D1.2.6 Emergency Phone Numbers

Emergency telephone numbers will be on site for medical and hyperbaric treatment, in addition to “emergency contact” numbers for divers.

D1.2.7 Diver Training Requirements

Divers used will be trained and experienced in the following:

- SCUBA diving procedures and techniques
- Emergency procedures
- Diving accident treatment procedures
- Proper operation and use of all SCUBA diving equipment
- Familiarity with the work being performed

D1.2.8 Nature of Work to Be Performed by the Divers

Divers will locate positions near the shoreline of NSA Panama City and deploy seepage meters to gather data over several days. Prior to the beginning of each day and each dive, a pre-dive safety meeting will take place discussing all site-specific issues. This discussion will include, but not be limited to, the task at hand, potential hazards, and the equipment and personnel involved with the work. The supervisor will be responsible for the site-specific safety meeting, for implementing all programs, and for ensuring all personnel are properly trained, properly informed, and properly equipped to do their jobs safely. He will in addition instruct all employees in the proper (safe) way of performing their work and make periodic reviews to ensure they continue to perform in a safe manner. He will ensure that all equipment and tools are maintained in good working condition and are being used properly in order to avoid equipment damage and potential for accidents. Additionally, he will investigate ALL accidents and prepare an accident report in the format included in this Dive Plan for all events requiring first aid or medical attention. He will be constantly aware that accident prevention is a priority.

Upon completion of the daily safety meeting, the dive team shall conduct the Equipment Procedures Checklist. All equipment shall be fueled, checked, and inspected to ensure operational integrity. The checklist shall be kept up to date. At no time shall a dive commence without thoroughly inspecting all equipment.

D1.2.9 Surface and Underwater Conditions

Surface conditions in St. Andrews Bay near NSA Panama City are usually calm, due to the protection of the surrounding land areas and low currents. Strong wind conditions can affect wave heights in the area. If wind conditions are severe enough to produce wave heights in excess of 2 ft at the work site, diving will be secured until conditions abate. Due to the shallow nature of the environment, visibility may be limited to less than 1 ft. This dive team has extensive experience in limited visibility dive operations.

D1.2.10 Maximum Depth and Bottom Times

Water depth will be 20 ft or less. All dives will take place at sea level.

All dives will stay within the No Decompression Limits as outlined by the U.S. Navy Diving Manual:

- 10 ft: 300 min
- 20 ft: 325 min
- 30 ft: 310 min
- 40 ft: 200 min

D1.2.11 Equipment Procedures Checklist and Requirements

D1.2.11.1 Cylinders

- Check condition of o-ring.
- Check all cylinders for proper pressure.
- Check all cylinders for proper visual inspection documentation (VIP decals).

D1.2.11.2 Scuba Equipment

- Check for air flow by breathing from all second stages.
- Check for leaks around all fittings.
- Check for functioning pressure gauge or computer.
- Test BC's manual and power inflators.
- Check BC for leaks.
- Check security of weight belt/integrated weight system.
- Inspect mask and fin straps for cracking.

D1.2.11.3 Final Preparations

- Verify that all necessary records, logs, and time sheets are on the dive station.
- Check that appropriate decompression and treatment tables are readily at hand.

D1.3 EMERGENCY MANAGEMENT PLAN

Accurate and timely reporting of accidents is mandatory. It is the responsibility of the diving supervisor to report all accidents or incidents immediately.

Ambulance	911
Fire Dept-EMERGENCY	911
Security Police	911
Poison Control Center	(800) 222-1222

Hyperbaric Facilities
Bay Medical Center
Frederick B Epstein, MD
Hyperbaric Medicine
615 N. Bonita Ave.
Panama City, FL, 32401
(850-747-6046), (850-872-0321 fax)

D1.3.1 Emergency Equipment

The following emergency medical equipment will be at the Job Site:

American Red Cross Standard First Aid Kits	one each
DAN Emergency Oxygen kit	one each
Cell phoneone each	one each
Cell phone batteries	two each

Every diver is first aid certified and is able to provide basic life support and pre-hospital emergency medical care for diving diseases and injuries. All injuries shall be treated immediately. Should an individual/diver need immediate treatment for a more serious injury, that person shall be removed from the water and an assessment then will be made to determine the extent of the injury and where that person should be treated.

D1.4 GENERAL ACTIVITY HAZARD ANALYSIS

Potential hazards include the following:

- Venomous aquatic/marine life
- Fouling or entanglement
- Mechanical injuries
- Water entry/exit injuries
- Unsafe weather conditions
- Flying after diving
- Decompression sickness
- Diver entrapment
- Injury to diver
- Drowning
- Air embolism
- Strangulation
- Loss of communication
- Water currents
- Diver caught in prop/wash
- Overexertion or exhaustion
- Diver struck by boat
- Boat drifting
- Underwater debris
- Disorientation due to low visibility
- Diver struck by falling object
- Fire hazard
- Stumbling hazards
- Wake danger
- Spills/leaks, environmental hazards

D1.5 SPECIFIC ACTIVITY HAZARD ANALYSIS

ACTIVITY HAZARD ANALYSIS PAGE 1 of 3

PRE-DIVE HAZARDS CONTROL REPORT

DATE SUBMITTED: June 26, 2004

<p>CONTRACT NO:</p> <p>ACTIVITY START:</p> <p>ACCEPTED BY CLIENT:</p> <hr/> <p>SIGNATURE</p> <hr/> <p>TITLE</p>		<p><u>NAME OF PROJECT:</u></p>
ACTIVITY	POTENTIAL HAZARDS	<i>PRECAUTIONARY ACTION & CONTROL TO BE TAKEN</i>
ALL BOATING ACTIVITIES	MAN OVERBOARD	ALL PERSONNEL TO ATTEND SAFETY BRIEFING BY CAPTAIN OF VESSEL PRIOR TO BEGINNING OF ALL PHASES OF WORK, AND ON FIRST DAY ON VESSEL FOR INDIVIDUALS.

ALL BOATING ACTIVITIES	SLIPS AND FALLS	SAFETY BRIEFING TO DISCUSS AREAS THAT COULD BE POTENTIAL TRIP HAZARDS. ALL SPILLS TO BE IMMEDIATELY CLEANED UP.
ALL DIVING ACTIVITIES	DROWNING	ADEQUATE TRAINING, PERIODIC DRILLING IN EMERGENCY PROCEDURES, UTILIZATION OF PROPER EQUIPMENT, AND ASSURANCE THAT EQUIPMENT IS IN GOOD CONDITION. SCUBA DIVERS WILL WEAR BUOYANCY COMPENSATORS, COMPETENT TENDERS UTILIZED, STANDBY DIVER WILL BE PRESENT, APPROPRIATE CRAFT USED, PROPER ENTRY AND EXIT FROM WATER AVAILABLE. SUPPORT PERSONNEL WILL WEAR SAFETY VEST WHEN APPLICABLE. AN OXYGEN RESUSCITATION SYSTEM WILL BE AVAILABLE.
ALL DIVING ACTIVITIES	AIR FAILURE	ALL DIVERS ARE EQUIPPED WITH STANDBY AIR SUPPLY. SHOULD THERE BE A FAILURE OF THE PRIMARY AIR SUPPLY, THE DIVE WILL BE ABORTED IMMEDIATELY.
ALL DIVING ACTIVITIES	FOULING OR ENTANGLEMENT	STUDY DIVE AREA AND ANTICIPATE OBSTRUCTIONS, SUCH AS LINES, CABLES, SNAGS, ETC., AS MUCH AS POSSIBLE. STANDBY OR BUDDY DIVER ASSISTS, GIVING VERY CAREFUL ATTENTION TO TIME AND DEPTHS WHILE DIVER IS FOULED; DETERMINE THE NEED FOR RECOMPRESSION.

ACTIVITY HAZARD ANALYSIS (CON'T) PAGE 2 of 3

PRE-DIVE HAZARDS CONTROL REPORT

ACTIVITY	POTENTIAL HAZARDS	PRECAUTIONARY ACTION & CONTROL TO BE TAKEN
ALL DIVING ACTIVITIES	MECHANICAL	SECURE TOPSIDE OBJECTS THAT MAY ACCIDENTALLY FALL ON DIVER(S). HANDLE TOOLS AND EQUIPMENT CAREFULLY AND ASSURE THAT SAFE CLEARANCE PROCEDURES ARE BEING COMPLIED WITH.
ALL DIVING ACTIVITIES	WATER ENTRY/EXIT INJURIES	A LADDER AND/OR PLATFORM WILL BE CONSTRUCTED TO ALLOW SAFE WATER ENTRY AND EXIT.
ALL DIVING ACTIVITIES	UNSAFE WEATHER CONDITIONS	DIVERS WILL NOT BE ALLOWED TO DIVE IF THE WEATHER CONDITIONS POSE A THREAT.
ALL DIVING ACTIVITIES	FLYING AFTER DIVING	DIVERS WILL NOT BE ALLOWED TO FLY WITHIN 12 HOURS AFTER PERFORMING A DIVE OR 24 HOURS AFTER MULTIPLE DIVES.
ALL DIVING ACTIVITIES	DECOMPRESSION SICKNESS	ALL DIVES WILL BE NO DECOMPRESSION DIVES. THE U.S. NAVY DIVE MANUAL DECOMPRESSION TABLES WILL BE USED AT ALL TIMES. THE TABLE AND SCHEDULE SELECTED FROM THE APPROPRIATE TABLE SHALL REFLECT THE EXACT OR NEXT DEEPER DEPTH AND EXACT OR LONGER BOTTOM TIME.
ALL DIVING ACTIVITIES	DIVER ENTRAPMENT	DIVERS WILL NOT ENTER ENCLOSED AREAS NOT INCLUDED IN DIVE PLAN. ENCLOSED SPACE DIVING SYSTEM WILL BE PROVIDED WHEN DIVERS PLAN TO ENTER ANY ENCLOSED SPACE.

ALL DIVING ACTIVITIES	INJURY TO DIVER	DIVER WILL PERFORM ALL SAFETY PRECAUTIONS TO PREVENT POSSIBLE INJURIES. COMPREHENSIVE DAILY PRE-DIVE MEETINGS WILL BE HELD.
ALL DIVING ACTIVITIES	LOSS OF COMMUNICATION	ALL COMMUNICATION WIRES AND BATTERIES WILL BE CHECKED DAILY PRIOR TO HOOK-UP OF COMMUNICATION SYSTEM.
ALL DIVING ACTIVITIES	AIR EMBOLISM	RATE OF ASCENT WILL NOT EXCEED 40 FPM (AS PER 1994 NAVY DIVING MANUAL). A ONE-MINUTE VENT WILL BE CONDUCTED PRIOR TO LEAVING BOTTOM TO INSURE BREATHING CONTROL.
ALL DIVING ACTIVITIES	STRANGULATION	DO NOT DIVE WITH OBSTRUCTIVE OBJECTS IN MOUTH, SUCH AS DENTURES, GUM, OR TOBACCO.

ACTIVITY HAZARD ANALYSIS (CON'T) PAGE 3 of 3

PRE-DIVE HAZARDS CONTROL REPORT

ACTIVITY	POTENTIAL HAZARDS	PRECAUTIONARY ACTION & CONTROL TO BE TAKEN
ALL DIVING ACTIVITIES	OVEREXERTION OR EXHAUSTION	THE DIVER SHOULD KNOW HIS OWN LIMITS AND STAY WITHIN THEM. STOP AND REST BEFORE BECOMING EXHAUSTED. MAINTAIN AND USE PROPER EQUIPMENT AT ALL TIMES.
ALL DIVING ACTIVITIES	HYPOTHERMIA	DRESS APPROPRIATE FOR UNDERWATER TEMPERATURE. ASCEND AT FIRST SIGN OF DISCOMFORT.
ALL DIVING ACTIVITIES	DIVER STRUCK BY EQUIPMENT	DIVE FLAGS WILL BE POSTED AT THE DIVE SITE PRIOR TO ENTERING WATER. THE APPROPRIATE AUTHORITIES WILL BE NOTIFIED THAT DIVERS ARE IN WATER AT INDICATED DIVE SITE. ALL TOPSIDE PERSONNEL WILL WATCH ALL EQUIPMENT TO PREVENT ANY EQUIPMENT ENTERING THE DIVE AREA UNNECESSARILY.
ALL DIVING ACTIVITIES	DIVER STRUCK BY EQUIPMENT	DIVE FLAGS WILL BE POSTED AT THE DIVE SITE PRIOR TO ENTERING WATER. THE APPROPRIATE AUTHORITIES WILL BE NOTIFIED THAT DIVERS ARE IN WATER AT INDICATED DIVE SITE. ALL TOPSIDE PERSONNEL WILL WATCH ALL EQUIPMENT TO PREVENT ANY EQUIPMENT ENTERING THE DIVE AREA UNNECESSARILY.

FUEL TRANSFER	SPILLS / LEAKS ENVIRONMENTAL HAZARD FIRE DANGER	STOP FLOW OF FUEL IMMEDIATELY. CONFINE THE SPILL BY USING ABSORBENT TOWELS OR DEPLOY CONTAINMENT BOOM. CONTACT THE COAST GUARD FOR OVERBOARD SPILL. WATCH FOR FIRE WHILE FUELING.
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DIVER INFORMATION SHEET

Name: _____ Age: _____ Sex: _____

Address: _____

Phone: _____

Diver Certifications: _____

Dive permits: _____

Date of last physical exam _____ Where taken? _____

CPR Certification: _____

First Aid Certification: _____

Person to notify in case of emergency: _____

Copies included with information sheet:

Dive Certification _____

CPR Card _____

First Aid Card _____

Dive permits _____ (please describe) _____

Please return forms to Dive Supervisor. Thank you.

DIVE OPERATION LOG SHEET

Date:

To be filled out BEFORE dive ops

Project:	Charge #: Code:		
Project Contact:			
Phone #:			
Diver #1:	Code #:	Phone Ext.:	
Diver #2:	Code #:	Phone Ext.:	
Diver #3:	Code #:	Phone Ext.:	
Diver #4:	Code #:	Phone Ext.:	
Safety Officer:	Code #:	Phone Ext.:	
Dive Location:	Emergency O2 : <input type="checkbox"/>		
	Weapons Pier		
Equipment list:	Flag <input type="checkbox"/> Wet suits <input type="checkbox"/> Masks <input type="checkbox"/> Tools: <input type="checkbox"/>	# of tanks 6 Dry suits <input type="checkbox"/> Computers <input type="checkbox"/> Seep meters <input type="checkbox"/>	BC's <input type="checkbox"/> Fins <input type="checkbox"/> Snorkels <input type="checkbox"/> Lift bag <input type="checkbox"/>
	Buoys <input type="checkbox"/>	Extra Wt <input type="checkbox"/>	Regs <input type="checkbox"/> Wt belts <input type="checkbox"/> Slate <input type="checkbox"/> Line <input type="checkbox"/> Comms <input type="checkbox"/>

Dive Plan:

To be filled out AFTER dive ops:

Were there any problems during ops? (If yes, pls explain)

Comments:

Signature of Diver

Date

Signature of Diver

Date

Signature of Safety Officer

Date

Please return completed forms to Dive Supervisor. Thank you.

APPENDIX D2

HEALTH AND SAFETY PLAN–NTC ORLANDO

D2.1 GENERAL DEMONSTRATION SAFETY REQUIREMENTS

Health and safety procedures during the demonstration will be in accordance with the existing Health and Safety Plans (HASP) for NTC Orlando (Southern Division Naval Facilities Engineering Command, 2004b) and, more specifically, OU 4 (Southern Division Naval Facilities Engineering Command, 2002). Health and safety aspects that are particular to this demonstration and not cited in the existing plans are detailed in the subsections below.

D2.2 SAFETY REQUIREMENTS FOR DIVING OPERATIONS

Depths in Lake Druid within the coastal monitoring footprint to be samples are up to 10 ft, while the lake reaches a depth of approximately 15 ft. Shallow-water SCUBA diving will be required. The diving safety procedures outlined in this section are to be followed, along with any applicable health and safety requirements in the HASP for the site (Southern Division Naval Facilities Engineering Command, 200b).

D2.2.1 Names and Duties Of Dive Team Members

Dive Supervisor: Christopher Field Smith

Divers: Chris Smith, Ron Paulsen, Jon Groves

Standby Diver: Any of the above when two are in the water

D2.2.2 Date, Time, and Location of Dive Operations

Date: Perform diving operations on or about 27 June–10 July 2005

Time: 08:00 through 16:30 on 4 to 10 days.

Location: Lake Druid, east shore, NTC Orlando, Florida

If diving support is required, the team will be conducting diving operations for approximately 5 days. The estimated total number of dives will be between two and four per day in shallow-water conditions less than 15 ft in depth. Diving operations will be primarily to deploy seepage detection/measurement equipment in Lake Druid adjacent to NTC Orlando.

D2.2.3 Diving Mode

The team will use open-circuit SCUBA diving as the diving mode for the fieldwork. The crew size will be a three-man team, all certified in cardiopulmonary resuscitation (CPR), first aid, and emergency oxygen administration, as well as certified to dive. At any time during diving operations, two members will be actively diving and the third member will act as the safety diver.

Diving will be performed in shallow waters from 4 to 15 ft of depth within 500 ft of the shoreline adjacent to NTC Orlando. Dives will be performed from shore or from a boat, and a ladder will be provided for egress of the divers when using the boat.

D2.2.4 Equipment

The team will use 80 f t³ aluminum cylinders filled with clean, dry air for the SCUBA diving air supply. The cylinders will have current hydro and visual inspections. The primary filling compressor will be located at The Dive Station (407- 843-3483; 3465 Edgewater Drive, Orlando, FL 32804), where the tanks will be leased. Dives will be performed with single tanks. Minimum equipment will consist of the following:

- 10 SCUBA Cylinders (3000 psi, 80 cf. ea.)
- 2 AGA full face mask systems w/ surface support communications
- 1 Boat first-aid kit
- 1 DAN O2 Emergency kit
- 1 Time keeping/logging device for all dive profiles
- 1 set of matrix diving paperwork
- 1 log
- 1 dive flag
- 3 sets of diver's equipment:
 - Regulator
 - Buoyancy Compensation Device (BCD)
 - Weight belt
 - Mask
 - Snorkel
 - Fins
 - Booties
 - Gloves
 - Wetsuit or dry suit/protective clothing
 - Knife
 - Dive light
- 2 Cellular telephones w/ emergency numbers

D2.2.5 Oxygen Resuscitation System

A Diver Alert Network (DAN) oxygen resuscitation system capable of providing oxygen for 30 minutes will be provided. All dive team members are currently qualified to operate this system

D.2.2.6 Emergency Phone Numbers

Emergency telephone numbers will be on-site for medical and hyperbaric treatment in addition to “emergency contact” numbers for divers.

D2.2.7 Diver Training Requirements

Divers used will be trained and experienced in the following:

- SCUBA diving procedures and techniques
- Emergency procedures
- Diving accident treatment procedures
- Proper operation and use of all SCUBA diving equipment
- Familiarity with the work being performed

D2.2.8 Nature of Diver's Work

Divers will locate positions near the shoreline of NTC Orlando and deploy seepage meters to gather data over several days. Prior to the beginning of each day and each dive, a pre-dive safety meeting will take place discussing all site-specific issues. This discussion will include but not be limited to the task at hand, potential hazards, and the equipment and personnel involved with the work. The supervisor will be responsible for the site-specific safety meeting, for implementing all programs, and for ensuring all personnel are properly trained, properly informed, and properly equipped to do their jobs safely. All employees will be instructed in the proper (safe) way of performing their work and the supervisor will make periodic reviews to ensure they continue to perform in a safe manner. The supervisor will also ensure that all equipment and tools are maintained in good working condition and are being used properly to avoid equipment damage and potential for accidents. Additionally, the supervisor will investigate ALL accidents and prepare an accident report in the format included in this Dive Plan for all events requiring first aid or medical attention. The supervisor will be constantly aware that accident prevention is a priority.

Upon completion of the daily safety meeting, the dive team shall conduct the Equipment Procedures Checklist. All equipment shall be fueled, checked, and inspected to ensure operational integrity. The checklist shall be kept up to date. At no time shall a dive commence without thoroughly inspecting all equipment.

D2.2.9 Surface and Underwater Conditions

Surface conditions in Lake Druid near NTC Orlando are usually calm, due to the protection of the surrounding land areas and low currents. Strong wind conditions can affect wave heights in the area. If wind conditions are severe enough to produce wave heights in excess of 2 ft at the work site, diving will be secured until conditions abate. Due to the shallow nature of the environment, visibility may be limited to less than 1 ft. This dive team has extensive experience in limited visibility dive operations.

D2.2.10 Maximum Depth and Bottom Times

Water depth will be 15 ft or less. All dives will take place at sea level. All dives will stay within the No Decompression Limits as outlined by the U.S. Navy Diving Manual:

- 10 ft: 300 min
- 20 ft: 325 min
- 30 ft: 310 min
- 40 ft: 200 min

D2.2.11 Equipment Procedures Checklist and Requirements

D2.2.11.1 Cylinders

- Check condition of o-ring
- Check all cylinders for proper pressure
- Check all cylinders for proper visual inspection documentation (VIP decals)

D2.2.11.2 Scuba Equipment

- Check for air flow by breathing from all second stages
- Check for leaks around all fittings
- Check for functioning pressure gauge or computer
- Test BC's manual and power inflators
- Check BC for leaks
- Check security of weight belt/integrated weight system
- Inspect mask and fin straps for cracking

D2.2.11.3 Final Preparations

- Verify that all necessary records, logs, and time sheets are on the dive station
- Check that appropriate decompression and treatment tables are readily at hand

D2.3 EMERGENCY MANAGEMENT PLAN

Accurate and timely reporting of accidents is mandatory. It is the responsibility of the diving supervisor to report all accidents or incidents immediately.

Ambulance	911
Fire Dept-EMERGENCY	911
Security Police	911
Poison Control Center	(800) 222-1222

D2.3.1 Hyperbaric Facilities

Florida Hospital Orlando Hyperbaric facility
601 East Rollins Street
Orlando, Florida 32803
407-896-6611

D2.3.2 Emergency Equipment

The following emergency medical equipment will be at the job site:

- 1 each American Red Cross Standard First Aid Kits
- 1 each DAN Emergency Oxygen kit
- 2 each Cell phone
- 2 each Cell phone batteries

Every diver is first-aid certified and can provide basic life support and pre-hospital emergency medical care for diving diseases and injuries. All injuries shall be treated immediately. Should an individual/diver need immediate treatment for a more serious injury, that person

shall be removed from the water and an assessment will be made at that time to determine the extent of the injury and where that person shall be medical treatment.

D2.4 GENERAL ACTIVITY HAZARD ANALYSIS

Potential hazards include the following:

- Venomous aquatic/marine life
- Fouling or entanglement
- Mechanical injuries
- Water entry/exit injuries
- Unsafe weather conditions
- Flying after diving
- Decompression sickness
- Diver entrapment
- Injury to diver
- Drowning
- Air embolism
- Strangulation
- Loss of communication
- Water currents
- Diver caught in prop/wash
- Overexertion or exhaustion
- Diver struck by boat
- Boat drifting
- Underwater debris
- Disorientation due to low visibility
- Diver struck by falling object
- Fire hazard
- Stumbling hazards
- Wake danger
- Spills, leaks, environmental hazards

D2.5 SPECIFIC ACTIVITY HAZARD ANALYSIS

ACTIVITY HAZARD ANALYSIS PAGE 1 of 3

PRE-DIVE HAZARDS CONTROL REPORT

DATE SUBMITTED: June 26, 2004

CONTRACT NO:

NAME OF PROJECT:

ACTIVITY START:

ACCEPTED BY CLIENT:

SIGNATURE

TITLE

<i>Activity</i>	<i>Potential Hazards</i>	<i>Precautionary Action & Control To Be Taken</i>
ALL BOATING ACTIVITIES	MAN OVERBOARD	ALL PERSONNEL TO ATTEND SAFETY BRIEFING BY CAPTAIN OF VESSEL PRIOR TO BEGINNING OF ALL PHASES OF WORK, AND ON FIRST DAY ON VESSEL FOR INDIVIDUALS.
ALL BOATING ACTIVITIES	SLIPS AND FALLS	SAFETY BRIEFING TO DISCUSS AREAS THAT COULD BE POTENTIAL TRIP HAZARDS. ALL SPILLS TO BE IMMEDIATELY CLEANED UP.
ALL DIVING ACTIVITIES	DROWNING	ADEQUATE TRAINING, PERIODIC DRILLING IN EMERGENCY PROCEDURES, UTILIZATION OF PROPER EQUIPMENT, AND ASSURANCE THAT EQUIPMENT IS IN GOOD CONDITION. SCUBA DIVERS WILL WEAR BUOYANCY COMPENSATORS, COMPETENT TENDERS UTILIZED, STANDBY DIVER WILL BE PRESENT, APPROPRIATE CRAFT USED, PROPER ENTRY AND EXIT FROM WATER AVAILABLE. SUPPORT PERSONNEL WILL WEAR SAFETY VEST WHEN APPLICABLE. AN OXYGEN RESUSCITATION SYSTEM WILL BE AVAILABLE.
ALL DIVING ACTIVITIES	AIR FAILURE	ALL DIVERS ARE EQUIPPED WITH STANDBY AIR SUPPLY. SHOULD THERE BE A FAILURE OF THE PRIMARY AIR SUPPLY, THE DIVE WILL BE ABORTED IMMEDIATELY.
ALL DIVING ACTIVITIES	FOULING OR ENTANGLEMENT	STUDY DIVE AREA AND ANTICIPATE OBSTRUCTIONS, SUCH AS LINES, CABLES, SNAGS, ETC., AS MUCH AS POSSIBLE. STANDBY OR BUDDY DIVER ASSISTS, GIVING VERY CAREFUL ATTENTION TO TIME AND DEPTHS WHILE DIVER IS FOULED; DETERMINE THE NEED FOR RECOMPRESSION.

ACTIVITY HAZARD ANALYSIS (CON'T)

PAGE 2 of 3

PRE-DIVE HAZARDS CONTROL REPORT

<i>Activity</i>	<i>Potential Hazards</i>	<i>Precautionary Action & Control To Be Taken</i>
ALL DIVING ACTIVITIES	MECHANICAL	SECURE TOPSIDE OBJECTS THAT MAY ACCIDENTALLY FALL ON DIVER(S). HANDLE TOOLS AND EQUIPMENT CAREFULLY AND ASSURE THAT SAFE CLEARANCE PROCEDURES ARE BEING COMPLIED WITH.
ALL DIVING ACTIVITIES	WATER ENTRY/EXIT INJURIES	A LADDER AND/OR PLATFORM WILL BE CONSTRUCTED TO ALLOW SAFE WATER ENTRY AND EXIT.
ALL DIVING ACTIVITIES	UNSAFE WEATHER CONDITIONS	DIVERS WILL NOT BE ALLOWED TO DIVE IF THE WEATHER CONDITIONS POSE A THREAT.
ALL DIVING ACTIVITIES	FLYING AFTER DIVING	DIVERS WILL NOT BE ALLOWED TO FLY WITHIN 12 HOURS AFTER PERFORMING A DIVE OR 24 HOURS AFTER MULTIPLE DIVES.
ALL DIVING ACTIVITIES	DECOMPRESSION SICKNESS	ALL DIVES WILL BE NO DECOMPRESSION DIVES. THE U.S. NAVY DIVE MANUAL DECOMPRESSION TABLES WILL BE USED AT ALL TIMES. THE TABLE AND SCHEDULE SELECTED FROM THE APPROPRIATE TABLE SHALL REFLECT THE EXACT OR NEXT DEEPER DEPTH AND EXACT OR LONGER BOTTOM TIME.

ALL DIVING ACTIVITIES	DIVER ENTRAPMENT	DIVERS WILL NOT ENTER ENCLOSED AREAS NOT INCLUDED IN DIVE PLAN. ENCLOSED SPACE DIVING SYSTEM WILL BE PROVIDED WHEN DIVERS PLAN TO ENTER ANY ENCLOSED SPACE.
ALL DIVING ACTIVITIES	INJURY TO DIVER	DIVER WILL PERFORM ALL SAFETY PRECAUTIONS TO PREVENT POSSIBLE INJURIES. COMPREHENSIVE DAILY PRE-DIVE MEETINGS WILL BE HELD.
ALL DIVING ACTIVITIES	LOSS OF COMMUNICATION	ALL COMMUNICATION WIRES AND BATTERIES WILL BE CHECKED DAILY PRIOR TO HOOK-UP OF COMMUNICATION SYSTEM.
ALL DIVING ACTIVITIES	AIR EMBOLISM	RATE OF ASCENT WILL NOT EXCEED 40 FPM (AS PER 1994 NAVY DIVING MANUAL). A ONE-MINUTE VENT WILL BE CONDUCTED PRIOR TO LEAVING BOTTOM TO INSURE BREATHING CONTROL.
ALL DIVING ACTIVITIES	STRANGULATION	DO NOT DIVE WITH OBSTRUCTIVE OBJECTS IN MOUTH, SUCH AS DENTURES, GUM, OR TOBACCO.

ACTIVITY HAZARD ANALYSIS (CON'T)

PAGE 3 of 3

PRE-DIVE HAZARDS CONTROL REPORT

<i>Activity</i>	<i>Potential Hazards</i>	<i>Precautionary Action & Control To Be Taken</i>
ALL DIVING ACTIVITIES	OVEREXERTION OR EXHAU.S.TION	THE DIVER SHOULD KNOW HIS OWN LIMITS AND STAY WITHIN THEM. STOP AND REST BEFORE BECOMING EXHAU.S.TED. MAINTAIN AND U.S.E PROPER EQUIPMENT AT ALL TIMES.
ALL DIVING ACTIVITIES	HYPOTHERMIA	DRESS APPROPRIATE FOR UNDERWATER TEMPERATURE. ASCEND AT FIRST SIGN OF DISCOMFORT.
ALL DIVING ACTIVITIES	DIVER STRUCK BY EQUIPMENT	DIVE FLAGS WILL BE POSTED AT THE DIVE SITE PRIOR TO ENTERING WATER. THE APPROPRIATE AUTHORITIES WILL BE NOTIFIED THAT DIVERS ARE IN WATER AT INDICATED DIVE SITE. ALL TOPSIDE PERSONNEL WILL WATCH ALL EQUIPMENT TO PREVENT ANY EQUIPMENT ENTERING THE DIVE AREA UNNECESSARILY.
ALL DIVING ACTIVITIES	DIVER STRUCK BY EQUIPMENT	DIVE FLAGS WILL BE POSTED AT THE DIVE SITE PRIOR TO ENTERING WATER. THE APPROPRIATE AUTHORITIES WILL BE NOTIFIED THAT DIVERS ARE IN WATER AT INDICATED DIVE SITE. ALL TOPSIDE PERSONNEL WILL WATCH ALL EQUIPMENT TO PREVENT ANY EQUIPMENT ENTERING THE DIVE AREA UNNECESSARILY.

FUEL TRANSFER	SPILLS / LEAKS ENVIRONMENTAL HAZARD FIRE DANGER	STOP FLOW OF FUEL IMMEDIATELY. CONFINE THE SPILL BY USING ABSORBENT TOWELS OR DEPLOY CONTAINMENT BOOM. CONTACT THE COAST GUARD FOR OVERBOARD SPILL. WATCH FOR FIRE WHILE FUELING.
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